Titre: Title:	Understanding the dynamics of industrial clusters : the case of the Canadian telecommunication equipment manufacturers
Auteur: Author:	Ziad Rotaba
Date:	2005
Type:	Mémoire ou thèse / Dissertation or Thesis
Référence: Citation:	Rotaba, Z. (2005). Understanding the dynamics of industrial clusters : the case of the Canadian telecommunication equipment manufacturers [Master's thesis, École Polytechnique de Montréal]. PolyPublie. https://publications.polymtl.ca/7678/

URL de PolyPublie: PolyPublie URL:	https://publications.polymtl.ca/7678/
Directeurs de recherche: Advisors:	
Programme: Program:	Unspecified

UNIVERSITÉ DE MONTRÉAL

UNDERSTANDING THE DYNAMICS OF INDUSTRIAL CLUSTERS:
THE CASE OF THE CANADIAN TELECOMMUNICATION EQUIPMENT MANUFACTURERS

ZIAD ROTABA

DÉPARTEMENT DE MATHÉMATIQUES ET DE GÉNIE INDUSTRIEL
ÉCOLE POLYTECHNIQUE DE MONTRÉAL

MÉMOIRE PRÉSENTÉ EN VUE DE L'OBTENTION
DU DIPLÓME DE MAÍTRISE ÈS SCIENCES APPLIQUÉES
(GÉNIE INDUSTRIEL)

AÔUT 2005

Your file Votre référence
ISBN: 978-0-494-16849-3
Our file Notre référence
ISBN: 978-0-494-16849-3

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ÉCOLE POLYTECHNIQUE DE MONTRÉAL

Ce mémoire intitulé:

UNDERSTANDING THE DYNAMICS OF INDUSTRIAL CLUSTERS:

THE CASE OF THE CANADIAN TELECOMMUNICATION EQUIPMENT MANUFACTURERS

Présenté par : ROTABA, Ziad
En vue de l'obtention du diplôme de : Maîtrise ès sciences appliquées
a été dûment accepté par le jury d'examen constitué de:

Mme DE MARCELLIS-WARIN, Nathalie, Doctorat, présidente
Mme BEAUDRY, Catherine, D.Phil., membre et directrice de recherche
M. SHEARMUR, Richard, Ph.D., member

To my beloved parents, sister and grandparents.

ACKNOWLEDGEMENT

First, I would like to thank my professor Catherine Beaudry, for without her guidance and support the work at hand would not have been a success.

I further would like to thank the personnel at Ecole Polytechnique and HEC, especially Manon Du Ruisseau who provided me with valuable information, with the shortest delays and Suzanne Guindon for all her help and support during my masters program.

I also would like to thank two professors from whom I learned significantly; Namely Prof. Jean Charles Bernard (Ecole Polytechnique, Genie Informatique) and Prof. Robert Gilbert (Ecole Polytechnique, Genie Industriel).

RÉSUMÉ

Le but principal de ce travail est de comprendre la dynamique des grappes industrielles Canadiennes de fabricants d'équipement de télécommunication. À cette fin, nous avons d'abord identifié les écoles des pensées suivantes : la science économique évolutionnaire, les théories de l'innovation et de l'organisation industrielle particulièrement en ce qui a trait à la création et la destruction d'entreprises ainsi que la concentration des marchés. Le moteur principal qui stimule la dynamique dans les grappes de haute technologie est sans aucun doute la technologie elle-même. Par conséquent, une recherche complète a été effectuée afin d'identifier les tendances technologiques. Nous avons identifié quatre tendances technologiques de base dans l'industrie de télécommunication notamment : la technologie sans fil (« wireless »), la technologie à large bande (« broadband »), les fibres optiques (« fiber ») et la transmission de la voix à l'aide d'Internet (« Voice over IP »).

Maintenant les bases théoriques et technologiques étudiées, nous avons recueilli des données pertinentes en vue de notre analyse. Une base de données longitudinale, au niveau de la firme a été construite en fusionnant diverses bases de données de façon à obtenir les données les plus exactes qui soient. Cette base de données nous a principalement permis d'identifier et de localiser géographiquement les diverses grappes industrielles du Canada produisant les équipements et technologies de télécommunication. Nous avons ainsi utilisé la somme de leurs ventes et de leurs employés comme indices de l'évolution de chacune de ces grappes identifiées.

Nous avons constaté que les firmes canadiennes d'équipement de télécommunication sont groupées principalement dans les grandes villes, particulièrement Ottawa, Montréal, Toronto, Calgary et Vancouver. L'effet de l'éclatement de la bulle technologique de ce secteur (Internet bubble boom and burst ou IBBB dans le texte) était tout à fait évident. La grappe de Toronto semble avoir souffert le plus, influencée par la détérioration rapide des actions de Nortel et l'effondrement apparent de l'industrie. Les ventes n'ont pas

seulement chuté à Toronto, elles ont également diminué à Vancouver, Montréal et Ottawa.

L'impact a été un peu retardé à Ottawa qui semble être l'endroit pour les petites entreprises innovatrices. On a découvert que les villes d'Ottawa, Saint Laurent et Burnaby sont les sources principales des activités de R&D dans l'industrie de télécommunication. Les firmes dans ces grappes fournissent traditionnellement leurs idées innovatrices à leurs sièges sociaux afin d'être commercialisées et vendues sur les marchés domestiques et internationaux. Puisque l'éclatement de la bulle est fondamentalement issue des marchés internationaux, soutenue par une chute de la demande locale, les entreprises d'Ottawa ont été affectées après un certain délai.

En ce qui concerne la taille des entreprises, nous avons trouvé que les grappes de Montréal et de Toronto ont généralement maintenu une diversification homogène en ce qui a trait à la taille de leurs entreprises, et que l'éclatement de la bulle a affecté presque chaque catégorie d'entreprises. Ce n'est pas vrai pour la grappe d'Ottawa, où par exemple, la principale réduction du nombre d'entreprises a été concentrée dans la catégorie de 5 à 9 employés.

Du côté technologique, nous pouvons noter que le degré de spécialisation de technologie est différent parmi les différentes grappes. Nous avons constaté qu'Ottawa est la grappe la plus productive par rapport aux divers types de technologie de télécommunication se protégeant par le fait même en augmentant les barrières technologiques à l'entrée dans la grappe. La grappe d'Ottawa domine les autres grappes au niveau de la production des technologies de fibre optique, grâce à Nortel et JDS Uniphase. Du côté des technologies de large bande et sans fil, les activités des entreprises semblent être très présentes dans différentes grappes notamment celles de Toronto, Vancouver, Ottawa, Montréal et Calgary. Naturellement, ceci est principalement dû à la demande croissante des utilisateurs de technologie sans fil, et de communication de médias. Il est également remarquable que la demande pour la technologie « Voice over IP» s'accélère d'une manière remarquable ; malheureusement nous n'avons pu établir de lien direct entre cette technologie et l'endroit d'où elle émerge.

D'une manière générale, tandis que les grandes villes financières, comme Toronto et Montréal détiennent la majorité des sièges sociaux des fabricants d'équipement de télécommunication, le rendement innovateur est principalement concentré à Ottawa suivi de Montréal, Toronto et Vancouver. En examinant les universités et leur contribution aux produits innovateurs dans les grappes où elles sont situées, nous avons constaté que les celles-ci contribuent d'une façon minimale aux produits innovateurs de ces grappes.

Dans notre recherche, nous avons étudié les travaux d'autres chercheurs qui ont utilisé les simulations pour comprendre la dynamique des marchés dans diverses industries. Nous avons alors présenté les fondements de la dynamique industrielle, un outil utilisé pour la simulation. Nous avons ensuite comparé les différents aspects de dynamique industrielle et des sciences économiques évolutionnaires, et nous avons expliqué pourquoi la dynamique industrielle est un outil très utile à l'étude des systèmes évolutionnaires.

Finalement, nous avons construit un modèle inspiré de Sterman (2000), qui a étudié l'évolution de la population. Le modèle a été construit en utilisant les théories de base des grappes industrielles et l'organisation industrielle, principalement en ce qui a trait à l'entrée et la sortie d'entreprises ainsi que les changements industriels. Le travail a été développé d'abord en utilisant les diagrammes de boucles de cause à effet (« Causal Loops»), par la suite nous avons mis en place un modèle de flux des stocks (« Stock Flow») qui décrit une grappe industrielle et ces diverses étapes d'évolution. Après avoir développé le système, la simulation a eu lieu de deux façons : la première pour étudier l'évolution de la grappe, et la seconde pour examiner la chute et la renaissance de la grappe, en introduisant l'effet d'un choc industriel important sur le système.

ABSTRACT

The prime aim of this work is to understand the dynamics of the Canadian telecommunication equipment manufacturers' clusters. In order to answer our main research question the following five minor research questions were identified: *First,* identify and locate geographically the various telecom industrial clusters all over Canada. *Second,* identify the strength of each industrial cluster. *Third, i*dentify firms' activities in each of the identified clusters. *Fourth,* measure the innovative output of each cluster. *Fifth, i*dentify technological trends that characterize each cluster.

In order to reach our main research objective we have accomplished the following: *First,* identified the various school of thoughts that will enable us solve the problematic at hand; mainly evolutionary economics, theories of innovation and industrial organization literature concerning entry, exit and market concentration. *Second,* a thorough research was established in order to identify the current technological trends in the telecommunication sector. *Third,* a longitudinal database, on the firm level was constructed. The database was built by merging various databases to finally attain the highest level of accuracy. This database enabled us to study, firms' entry, exit, age and how it evolved with time. *Fourth, we* constructed a database that described innovative output on the clusters levels. *Fifth,* we used descriptive statistical tools to understand the dynamics of the studied clusters. *Sixth,* a simulation model was constructed to simulate entry, exit, and the cluster life cycle.

After performing our analysis, we have found that Canadian Telecommunication Equipment firms clustered mainly in big cities namely: Ottawa, Montreal, Toronto, Calgary and Vancouver. The four basic booming technological trends in the telecommunication industry namely; wireless, broadband, fiber and Voice over IP technologies. In order to assess the strength of each cluster we used: sales and firms size as measures. The effect of the Internet Bubble Boom and Burst (IBBB) affected

financial capitals, namely: Montreal, Toronto, and Vancouver. Some kind of a delayed response affected Ottawa. Ottawa, together with Montreal (Saint-Laurent) and Vancouver (Burnaby), seem to be the place for smaller, innovative firms and the main source of R&D activities in the telecommunication industry.

With respect to firms' size, we have found, that Montreal and Toronto clusters generally held a homogenous diversification in terms of firms sizes, and that the crisis, almost affected each and every category. This was not true in Ottawa, where for example the main reduction in firms' sizes was mainly focused on the 5 to 9 employees' category. Generally speaking, we have found that smaller firms are the ones that mainly suffered the downturn of the IBBB, with a different magnitude among different clusters, with less harm done to the biggest firms. We have concluded the following: when the telecommunication industry started to mature in the 80s, older firms unable to adapt died, while newly born firms had the competitive advantage to survive with their newly innovative ideas, however when submitted to the industry shakeout, newer firms died, while older ones, with more adequate financial structure survived.

From our analysis, we have found that the Canadian Telecommunication Equipment Industry is a highly protected industry. The several Incumbent firms enjoy a protection from entry, building technological 'Barriers to Entry' and offering aggressive protection to early entrants. On the technology side, we can notice that the degree of technology specialization is different among different clusters. This could be witnessed on both, firms' activities and patenting activities, in the various clusters studied.

We have found that the Ottawa cluster takes the lead producing all sorts of telecommunication technologies hence protecting itself, by increasing the cluster's technologically barriers to entry. On the broadband and wireless technology sides, firms' activities seem to be active in all studied clusters. Of course this is mainly driven by the increasing demand from end users for wireless, and media communication. It is also remarkable that the Voice over IP (VoIP) technology is still gaining ground; however, we cannot determine yet any kind of relation between technology and location. We also discovered that Waterloo is also an active firm with respect to wireless technology.

Big clusters such as Vancouver, Montreal, Toronto, Ottawa and Calgary, each contribute to patenting in the services side, and this is driven mainly by demand from operators scattered geographically in each region. With time, patenting activities with respect to telecommunication software management seems to be remarkably accelerating, driven mainly by the Ottawa region.

The current technology convergence, is now putting more pressure on the software layer to control network traffic, and put more security on networks. Also we have seen that voice technology is currently witnessing a remarkable advance, due to the emergence of the VoIP technology, the same phenomenon was witnessed in the wireless technology that became almost mandatory as a mean for telecommunication.

Generally speaking, while big financial cities, namely Toronto and Montreal hold the majority of headquarters for manufacturing firms; innovative output is mainly concentrated primarily in Ottawa (Kanata and Nepean) followed by Montreal (Saint-Laurent), Toronto and Vancouver.

Due to the intensive R&D structure that this industry holds, primarily controlled by incumbent firms, Universities contribute indirectly to the innovative output of the telecommunication equipment clusters, by collaborating with the industry.

Finally, we have introduced industrial dynamics as a tool to simulate entry, exit, and the cluster life cycle. Using such a methodology, to our knowledge, is the first in the field of the industrial clusters domain.

CONDENSÉ

Le but principal de ce travail est de comprendre la dynamique des grappes industrielles Canadiennes de fabricants d'équipement de télécommunication. À cette fin, nous avons d'abord identifié les diverses écoles des pensées suivantes : la science économique évolutionnaire, les théories de l'innovation et de l'organisation industrielle particulièrement en ce qui a trait à la création et la destruction d'entreprises ainsi que la concentration des marchés. Tandis que les chercheurs canadiens ont concentré leurs efforts sur les diverses industries de haute technologie comme les industries de la biotechnologie, la technologie de l'information et de la communication (ICT), aucun d'eux n'a abordé l'industrie canadienne d'équipements de télécommunication en particulier.

Le moteur principal qui stimule la dynamique dans les grappes de haute technologie est sans aucun doute la technologie elle-même. Par conséquent, une recherche complète a été effectuée afin d'identifier les tendances technologiques courantes dans le secteur de la télécommunication. Nous avons examiné l'histoire de l'industrie des télécommunications du 17ème siècle à nos jours, et avons tracé l'évolution des diverses innovations dans les matériels de transmission depuis l'invention du télégraphe et de son déploiement dans la communication, en passant par l'invention de téléphone au début du 20ème siècle, jusqu'aux tendances technologiques courantes.

Nous avons vu qu'en général l'industrie a commencé par des innovations majeures ou « breakthrough » (comme celle de Marconi, Bell et Morse) jusqu'à ce que l'industrie devienne extrêmement complexe, avec l'introduction du transistor dans les années 1950 et ensuite avec l'introduction des communication de données (« data ») au début des années 1980. Nous avons aussi étudié le rôle fondamental de la déréglementation de l'industrie des télécommunications, et son impact sur l'entrée des firmes rivales faisant concurrence au monopole de Bell (au Canada) et de AT&T (aux États-Unis).

Nous avons identifié quatre tendances technologiques de base dans l'industrie de télécommunication notamment : la technologie sans fil (« wireless »), la technologie à large bande (« broadband »), les fibres optiques (« fiber ») et la transmission de la voix à l'aide d'Internet (« Voice over IP »).

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Nous avons constaté que les firmes canadiennes d'équipement de télécommunication sont groupées principalement dans les grandes villes, particulièrement Ottawa, Montréal, Toronto, Calgary et Vancouver. L'effet de l'éclatement de la bulle technologique de ce secteur (Internet bubble boom and burst ou IBBB dans le texte) était tout à fait évident. La grappe de Toronto semble avoir souffert le plus, influencée par la détérioration rapide des actions de Nortel et l'effondrement apparent de l'industrie. Tandis que la ville de Brampton souffrait spécifiquement des pertes énormes, nous avons remarqué une augmentation récente des ventes dans la région de Waterloo, dues à la firme `Research in Motion' qui fabrique principalement des technologies sans fil. Les ventes n'ont pas seulement chuté à Toronto, elles ont également diminué à Vancouver, Montréal et Ottawa.

Alors que les plus grandes villes financières, comme Toronto, Montréal et Vancouver ont été directement affectées par les changements dans l'industrie suite à l'éclatement de la bulle technologique, l'impact a été un peu retardé à Ottawa. Tandis que la plupart des fabricants de télécommunication ont leurs siège sociaux (« headquarters ») à Toronto, Montréal, et Vancouver (visant à se grouper près de leurs institutions financières, et bénéficier d'infrastructures telles que les aéroports), la grappe d'Ottawa semble être l'endroit pour les petites entreprises innovatrices.

En effet on peut voir que le bureau principal de recherche-développement (R&D) de Nortel est situé à Ottawa. Parce que l'industrie des télécommunications est naturellement une industrie internationale, et que la demande pour ses produits vient des marchés internationaux, les entreprises Canadiennes situées dans les villes financières Canadiennes on d'abord été affectées par l'éclatement de la bulle. Après un certain temps, les firmes situées a Ottawa ont commencé à souffrir.

Les villes d'Ottawa, Saint-Laurent et Burnaby sont les sources principales des activités de R&D dans l'industrie de télécommunication. Les firmes dans ces grappes fournissent traditionnellement leurs idées innovatrices à leurs sièges sociaux afin d'être commercialisées et vendues sur les marchés domestiques et internationaux. Puisque l'éclatement de la bulle est fondamentalement issue des marchés internationaux, soutenue par une chute de la demande locale, les entreprises d'Ottawa ont été affectées après un certain délai.

En ce qui concerne la taille des entreprises, nous avons trouvé que les grappes de Montréal et de Toronto ont généralement maintenu une diversification homogène en ce qui a trait à la taille de leurs entreprises, et que l'éclatement de la bulle a affecté presque chaque catégorie d'entreprises. Ce n'est pas vrai pour la grappe d'Ottawa, où par exemple la principale réduction du nombre d'entreprises a été principalement concentrée dans la catégorie de 5 à 9 employés. D'une manière générale, nous avons constaté que les petites entreprises sont celles qui ont principalement souffert de l'éclatement de la bulle Internet, avec un impact différent selon les différentes grappes, et que l'impact a été moindre pour les plus grandes entreprises. En étudiant l'échantillon des firmes provenant de « Cancorp Financials », nous avons découvert qu'en général, les entreprises les plus âgées étaient celles qui sortaient du marché Canadien des télécommunications.

Ceci peut être expliqué par le fait que tandis que l'industrie de la télécommunication commençait à mûrir dans les années 80, les entreprises les plus âgées, incapables de s'adapter technologiquement, ont fermé boutique, tandis que les petites entreprises soutenues par des avantages technologiques concurrentiels ont survécu grâce à leurs idées innovatrices. Cependant, une fois soumises au choc qu'a subi l'industrie au début du siècle, les entreprises les plus jeunes ont dû se retirer du marché et les entreprises les plus âgées ont survécu.

De ceci, nous pouvons déduire une conclusion intéressante : si le changement technologique (« shift ») est soutenu par une croissance économique, les idées innovatrices peuvent garantir la croissance des petites entreprises, et la chute des grandes entreprises incapables de s'adapter technologiquement. En cas de choc tel que l'éclatement de la bulle technologique ou de changement majeur (« shakeout ») de l'industrie, les entreprises ayant une capacité financière plus grande survivent, tandis que les firmes les plus innovatrices sont plus sujettes à la banqueroute dans leurs propres grappes. Veuillez noter que la majorité de entreprises dans l'industrie des télécommunication sont des sociétés par actions, et par conséquent, soutenues par des capitaux intenses et des structures financières compliquées qui leur permettent, d'abord, de survivre aux blessures économiques et technologiques, et ensuite à acquérir les petites entreprises qui constituent une menace technologique par leurs produits concurrentiels (substituts), par exemple. L'acquisition de telles entreprises et des firmes fabriquant des produits complémentaires leur permet de diversifier leur portefeuille de produits de façon à servir un plus grand nombre de segments de leur clientèle.

Après avoir identifié des grappes et leur caractéristiques générales, nous avons étudié les firmes et les technologies qui caractérisent ces grappes en utilisant l'age de ces entreprises, leurs activités technologiques principales et leur rendement en terme d'innovations (à l'aide des brevets attribués par le bureau canadien de la propriété intellectuelle ou CIPO).

Lors de notre analyse, nous avons constaté que l'industrie canadienne de fabrication d'équipements de télécommunication est une industrie fortement protégée. Les entreprises qui essaient de percer ces marchés font face à une barrière à l'entrée agressive et stimulée par les anciens fondateurs (tels Nortel, JDS Uniphase et Ericsson Canada) et qui se caractérise par des coûts de R&D élevés.

Du côté technologique, nous pouvons noter que le degré de spécialisation de technologie est différent parmi les différentes grappes. Nous avons constaté qu'Ottawa est la grappe la plus productive par rapport aux divers types de technologie de télécommunication se protégeant par le fait même en augmentant les barrières technologiques à l'entrée dans la grappe. La grappe d'Ottawa domine les autres grappes au niveau de la production des technologies de fibre optique, grâces aux Nortel et JDS Uniphase. Du côté des technologies de large bande et sans fil, les activités des entreprises semblent être très présentes dans différentes grappes notamment celles de Toronto, Vancouver, Ottawa, Montréal et Calgary. Naturellement, ceci est principalement dû à la demande croissante des utilisateurs de technologie sans fil, et de communication de médias. Il est également remarquable que la demande pour la technologie « Voice over IP» s'accélère d'une manière remarquable ; malheureusement nous n'avons pas pu établir de lien direct entre cette technologie et l'endroit d'où elle émerge.

Waterloo est également une grappe active en ce qui concerne la technologie sans fil et ceci est principalement dû à la firme « Research in Motion » qui produit des brevets en technologie sans fil (sa compétence principale) et récemment en technologie de fibre optique, visant probablement à diversifier son portefeuille de produits.

Les grandes grappes industrielles de Vancouver, Montréal, Toronto, Ottawa et Calgary, contribuent chacune à l'innovation dans le domaine des services. Ceci est dû principalement à la demande provenant des opérateurs dispersés géographiquement dans chaque région afin de satisfaire leurs clients résidentiels. Au fil du temps, le brevetage des activités de gestion de logiciels de télécommunication semble s'accélérer remarquablement, particulièrement dans la région d'Ottawa.

La convergence actuelle de technologie, exerce maintenant plus de pression sur la partie logicielle du système afin de contrôler le trafic des réseaux, et ajouter un niveau de sécurité accrû sur les réseaux. Également, nous avons vu que la technologie relative à la transmission de la voix est témoin actuellement d'une avance remarquable, en raison de l'apparition de la technologie VoIP, qui semble suivre la même diffusion rapide que la technologie sans fil qui dernièrement est devenue presque obligatoire comme moyen de télécommunication.

D'une manière générale, tandis que grandes villes financières, comme Toronto et Montréal détiennent la majorité des sièges sociaux des fabricants d'équipement de télécommunication, le rendement innovateur est principalement concentré à Ottawa suivi de Montréal, Toronto et Vancouver.

Au niveau de la firme, les entreprises les plus âgées, se caractérisant par de larges dépenses de R&D, détiennent la majorité des activités innovatrices (mesurée par le nombre de brevets). Nous avons constaté que l'âge de ces entreprises a joué un rôle principal dans la survie des entreprises. Il est important de noter que Niosi (2000) a classé l'industrie du matériel de communication comme un vieil oligopole, datant de cent ans, similaire aux autres industries qui détiennent des structures industrielles semblables, telles que l'industrie aéronautique (80 ans) et l'industrie pharmaceutique (120 ans). Ces industries sont moins dispersées en terme de structure industrielle que les industries les plus récentes comme la biotechnologie et l'industrie du logiciel.

Généralement, les entreprises les plus âgées qui ont survécut et ont su s'adapter aux diverses circonstances économiques et technologiques avec le temps, ont établi des barrières à l'entrée importantes, en laissant survivre seulement les petites entreprises qui produisent des innovations radicales. Un exemple d'une grande entreprise est Nortel qui investit intensivement en R&D pour augmenter les barrières faces aux petites entreprises qui viennent d'émerger.

Ces résultats concernant la R&D dans la domaine des télécommunications sont également soutenus par d'autres chercheurs comme Godoe (2000) et Rao (1999) qui ont constaté que l'intensité de la R&D en télécommunication a doublé de 5.1% à 10.3%. Rao (1999) a expliqué que cette augmentation dramatique de l'intensité de la R&D est attribuable à la demande croissante pour les nouveaux produits et services dans le secteur des télécommunications ce qui nécessite des dépenses de R&D extraordinaires.

En examinant les universités et leur contribution aux produits innovateurs dans les grappes où elles sont situées, nous avons constaté que les celles-ci contribuent d'une façon minimale aux produits innovateurs de ces grappes. Naturellement ceci ne nie pas le fait que les universités contribuent à la croissance innovatrice de leurs grappes, ce qui cependant est fait indirectement par la collaboration avec les fabricants majeurs de matériel de télécommunication.

Après avoir expliqué la structure de l'industrie canadienne de télécommunication, et sa dynamique, nous présenterons la dynamique industrielle comme un outil pour simuler l'entrée et la sortie des entreprises ainsi que le cycle de vie des grappes. L'utilisation d'une telle méthodologie est, à notre connaissance, une première dans le domaine des grappes industrielles.

Dans notre recherche, nous avons étudié les travaux d'autres chercheurs qui ont utilisé les simulations pour comprendre la dynamique des marchés dans diverses industries. Nous avons alors présenté les fondements de la dynamique industrielle, un outil utilisé pour la simulation. Nous avons ensuite comparé les différents aspects de la dynamique industrielle et des sciences économiques évolutionnaires, et nous avons expliqué pourquoi la dynamique industrielle est un outil très utile à l'étude des systèmes évolutionnaires.

Nous avons construit un modèle inspiré de Sterman (2000), qui a étudié l'évolution de population. Le modèle a été construit en utilisant les théories de base des grappes industrielles et l'organisation industrielle, principalement en ce qui a trait à l'entrée et la sortie de entreprises ainsi que les changements industriels. Le travail a été développé d'abord en utilisant les diagrammes de boucles de cause à effet (« Causal Loops»), par la suite nous avons mis en place un modèle de flux des stocks (« Stock Flow») qui décrit une grappe industrielle et ses diverses étapes d'évolution. Après avoir développé le système, la simulation a eu lieu de deux façons : la première pour étudier l'évolution de la grappe, et la seconde pour examiner la chute et la renaissance de la grappe, en introduisant l'effet d'un choc industriel important sur le système.

Pour conclure, nous avons identifié cinq grappes principales produisant des équipements de télécommunication, notamment Montréal, Ottawa, Toronto, Calgary et Vancouver. Les quatre technologies de télécommunication principales sont la technologie sans fil (« wireless »), la technologie à large bande (« broadband »), les fibres optiques (« fiber ») et la transmission de la voix à l'aide d'Internet (« Voice over IP »). Ottawa est le leader en ce qui concerne toutes les technologies et semble aussi être un monopole en ce qui a trait aux technologies de fibre.

La technologie à large bande (« broadband ») et la technologie sans fil («wireless ») sont dispersées entre les 5 grappes identifiées, ce qui est probablement attribuable à la demande croissante pour la communication de données et de médias.

L'éclatement de la bulle technologique a durement affecté les villes financières, principalement Toronto, Montréal et Vancouver, avec l'impact le plus frappant à Toronto où Nortel est localisé. Les effets de l'éclatement de la bulle ont été légèrement retardés à Ottawa, centre des activités innovatrices et non financières.

En outre, nous avons noté qu'Ottawa accueille principalement des petites sociétés qui ont été affectées par l'éclatement de la bulle, tandis que les grandes villes se composants d'une variété d'entreprises de taille différentes ont été moins affectées par cette crise. En général, l'éclatement de la bulle technologique a accentué la disparition des petites entreprises plus innovatrices à Ottawa, tandis que de plus grandes sociétés moins innovatrices possédant une structure financière plus robuste ont été moins affectées.

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ACD	Automatic Call Distribution
ADSL	Asynchronous Digital Subscriber Line
ARPANET	Advanced Research Project Agency Network
ASP	Application Service Providers
ATM	Asynchronous Transfer Mode
CBP	Canadian Business Patterns
CIPO	Canadian Intellectual and Property Office
CMTS	Cable Modem Termination Systems
CTEM	Canadian Telecommunication Equipment Manufacturers
D&B	Dun and Bradstreet
DSL	Digital Subscriber Line
FCC	Federal Communication Commission
FTC	Federal Trade Commission
GSM	Global Systems for Mobile communication
IBBB	Internet Bubble Boom and Burst
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISP	Internet Service Providers
ITU	International Telecommunication Union
KTS	Key Telephone Systems
LAN	Local Area Network
M&A	Mergers and Acquisitions
MSC	Mobile Switching Centers
NAICS	North American Industry Classification System

OSI	Open Systems Interconnection
PBX	Private Branch Exchange
PSTN	Public Switched Telephone Network
SIC	Standard Industrial Classification
SME	Small and Medium Enterprises
SONET	Synchronous Optical Network
TCP/IP	Transfer Control Protocol / Internet Protocol
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TEM	Telecommunication Equipment Manufacturers
TEMC	Telecommunication Equipment Manufacturers Cluster
USPTO	United States Patents and Trademark Office
VoIP	Voice over Internet Protocol
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access digital technology
WDM	Wavelength Division Multiplexing

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INTRODUCTION

The nature of the telecommunication industry is quite complex. It started with breakthrough innovations, like the telephone invented by Bell, radio transmission invented by Marconi, then was followed by incremental innovations. With the scientific advances occurring in the field of materials, electronics and microwave, the telecommunication industry was transformed from a simple connection between 2 nodes connected by copper wires, towards more complicated switches, coupled with long overseas wires carrying voice between different continents.

Operators at that time, had their own manufacturing facilities, like Bell and Western Electric, its manufacturing arm. This way Bell and AT&T owned a perfect monopoly on telecommunication equipment. After market deregulation, more firms began to enter the telecommunication equipment market manufacturing telecommunication products; however operators' manufacturing arms held a market monopoly. Due to the nature of telecommunication products, that were highly mechanical in nature, firms manufacturing these equipment diversified their production into highly mechanical products, some producing sound like the phonograph, and others only mechanical devices such as simple control switches, used in electrical control. An example of this is Western Electric that later became Northern Telecom then Nortel.

In the 1950s new technologies emerged, mainly driven by the advances in electronic material, and the transistor was invented. The transistor invention had a tremendous impact on Telecommunication Equipment Manufacturers firms (TEMs), where switching instead of being implemented mechanically, electronics are now used to do switching. Again, firms that failed to adapt perished, and others who were able to keep up with the technological advances in transistors and electronics were able to survive; Northern Telecom is a classical example.

In the 1970s, fiber technology was exploited, and Northern Telecom was one of the leaders in that domain. However since the services part of telecommunication was not that mature yet, fiber technologies were under exploitation but were not heavily used commercially.

In the beginning of the 1980s, another breakthrough innovation rose up, and the internet was opened for public use. Firms like Cisco emerged, providing products such as data routers and switches. With advances in computer and software industry, putting more and more data on networks became easier, and currently we are able to witness networks that converge. Data communication firms are going into voice telecommunication markets, and vice versa. Finally, all data is treated as zeros and ones, whether it is voice, media, or highly complex data. Equipment now is able to transmit, switch and route this wide spectrum of data, and this puts more pressure on vendors to provide more bandwidth for operators and users. The current demand for bandwidth has revived the interest in fibers, and firms have started doing more innovations that serves the fiber technology.

The prime aim of this work is to understand the dynamics of the Canadian telecommunication equipment manufacturers' clusters. In order to understand these dynamics we first have identified the various schools of thought that will enable us to investigate the problem at hand; mainly evolutionary economics, theories of innovation and industrial organization literature concerning entry, exit and market concentration. It has been noticed that while Canadian researchers focused their efforts on various high technology industries like the biotechnology industry, the information and communication technology (ICT) and other manufacturing industries; none of them tackled the Canadian telecommunication equipment industry specifically.

The following minor research questions or objectives were identified: *First*, we will identify and locate geographically the various telecom industrial clusters all over

Canada. *Second,* we will identify the strength of each cluster, using sales and employment figures. *Third,* we will measure the innovative output of each cluster, and identify major technological trends that are bound to location if there is any.

In order to reach our main research objective we accomplished the following: *First,* we identify the various schools of thought that will enable us investigate the problem at hand. Second, we will conduct a thorough research in order to identify the current technological trends in the telecommunication sector. *Third,* we will assemble a longitudinal database on the firm and cluster levels. This database will enable us to study, firms' entry and age, and how it evolved with time. *Fourth,* and in order to study the innovative capacity of each cluster, we will construct a database that describes innovative output at the firm, and regional levels.

After data is extracted and databases built, we will use descriptive statistical tools in order to understand the dynamics of the studied clusters. Finally simulations, using industrial dynamics tools, will be constructed to simulate entry, exit, and the cluster life cycle.

CHAPTER 1 - LITERATURE REVIEW

This chapter reviews the theoretical backbone of the research at hand. Its first aim is to shed some light on the evolutionary school of economics, or what Nelson and Winter (1982) called 'neo Schumpeterian' economics, and to introduce its differences from the Neo Classical School in section 1.1. The second aim is to introduce the notion of "industrial clusters" in section 1.2, with its different schools of thought, as well as different studies done on different countries and sectors globally. In section 1.3, Canadian clusters literature is presented. In section 1.4, entry and exit literature from the field of industrial organization is presented. In section 1.5, literature review summary and main research hypothesis will be derived. Finally section 1.6 concludes.

1.1 Evolutionary Economics

Nelson and Winter (1982) are the main founders of what is called evolutionary economics. Their classical text lays the foundation of evolutionary economics. The main concept behind evolutionary economics is inspired from the field of biology. According to Nelson and Winter (1982), the classical general equilibrium theory is a simplification of what really happens in the real world as orthodox models ignore the complexity of reality. It is worth mentioning that with evolutionary theory, firms are still motivated by profits. Their actions however are not 'profit maximizing'. For example firms sometimes act with a certain strategy to drive unprofitable, competitive firms out of business. Therefore the overall system modeling should not address 'industry equilibrium'; rather it should start from the firm level; modeling firms (or Agents) with certain rules and capacities that are time variant.

Their criticism of the classical way of understanding firms' behavior, states that: *First,* it over simplifies as it does not take into consideration environmental changes for example; *Second*, it does not take into account 'historical change'; *Third*, it does not take into account that markets do not often enjoy perfect information, where information is generally hidden among the different players, and often each player in the market has to act based upon known perfect information, and unknown imperfect information. Finally, it ignores the fact that firms learn with time, and that their ability to take better decisions is based on management capabilities and understanding market dynamics. It is also crucial to highlight that if a fast evolutionary process occurs, like an industry shakeout, we might judge it as revolutionary. Therefore it all depends on when we start observing and when we stop.

According to Nelson and Winter (1982), *on the one hand*, classical models try to highlight "Why are the rules the way they are", where rules often reflect maximizing behavior of the firm. Maximization models usually contain 3 components: *First*, the objective function that is what the firm seeks to maximize (e.g. trying to maximize profits); *Second*, the choice set, or the set of things the firm knows how to do (e.g. production set); *Third*, maximizing choice rationalization, in other words, the firm's action is viewed as the result of the choice of action that maximizes the degree to which its objective is achieved. *On the other hand,* the structure of an evolutionary model is all about internal routines that control the model. These routines are the properties and features of the firm that determine its behavior. A firm selects these routines on the basis that some routines do better than others.

It is important to note that these routines that govern firms' behavior have functional characteristics (Hodgson and Geoffrey, 1999). Nelson and Winter name these routines the 'Organizational Memory' of the firm. They draw a parallel between economics and biology: routines and biological genes are similar due to their durability and their capacity to replicate. However since innovative activity is not only the result of a routine, and that innovation is sometimes the product of a hazardous process, Nelson and Winter (1982) recognized the importance of stochastic elements in the decisions and their outcomes. Search in the routines of firms, corresponds to mutation in biology:

firms keep searching for better routines to enhance performance and increase profitability. However there is a limit to the search, for example, if firms are seen as profitable enough by their management, they cease searching for a while, this, as Hodgson and Geoffrey (1999) highlighted, is similar to what Herbert Simons (1957) introduced as the 'Satisficing Idea'. Now if firms start losing profit to their competitors, they start searching again, an example of this as a strategy, is investing in R&D to re-gain firms' competitiveness and profitability. This phenomenon is quite interesting, especially in the telecommunication sector, where using R&D and fostering innovative ideas, helped firms like Nortel (as we will see later) survive the different technological and economical shakeouts.

1.2 Industrial Clusters

Several researchers have addressed the topic of industrial clusters. A geographical cluster is defined as a strong collection of related companies located in a small geographical area. Industrial clustering is an important phenomenon especially with the increasing importance of Small and Medium Enterprises (SMEs) in the current highly competitive economies.

Audretsch (1995) explains that the United States industries were backed up by a large amount of capital that enabled the exploitation of scale economies. At some point in time, it was thought that large corporations had positive impacts on industrialized economies; a theory that was supported by Schumpeter who wrote that large-scale establishments have become one major force fostering progress and expansion of output. At that time, the potential of perfect competition as a source of economic growth was minimized; the eastern and western economies were often dominated by powerful enterprises that enjoyed great monopolies and were often supported by their governments.

Nowadays, this theory has changed, and market efficiency is generally believed to be achieved through perfect competition. SMEs in fact, are the agents that brought the west to its currently advanced, competitive situation (Audrestch, 1995), not large enterprises. It was classically thought that large companies should have a competitive edge over others due to their capital advantage that leads to economies of scale. A series of studies however found that small firms are more innovative than larger ones, hence destroying this preconception.

Executives of large communication equipment companies realized that proximity is crucial especially for firms in high-tech industries. Mr. Chambers, Cisco's CEO, highlighted the importance of proximity when saying, "If you are doing a large acquisition, the minute you get on an airplane, you have got a problem" (Paulson, 2001). Barry Eggers, former leader of Cisco Business Development explicitly said: "Geographic proximity. This is always a tough one. If you look at some of the acquisitions that haven't worked out as well, geography plays a key role" (Paulson, 2001). The above statements from top executives of Cisco not only highlight the importance of geographical proximity and hence agglomeration, but it also demonstrates that location is a key strategic decision for top executives when choosing the location of their plants.

Several researchers examined the spatial dimension of links between firms and other entities like such as universities. Audretsch and Stephan (1996) examined the role of company-scientist location links in the case of biotechnology. The researchers examined the question whether links between university scientists and biotechnology companies are geographically bounded, and whether the spatial dimension of geographic links between biotechnology firms and scientists is shaped by the role and characteristics of the scientist. They found that proximity did matter to establish "formal ties" but not much more than that. The study showed that scientists participate in networks that are 70% geographically bounded. It was also found that proximity is shaped by the role played by the scientist where for example 40% of university based founders of biotechnology firms are affiliated with firms outside their region. As a general conclusion, Audretsch and Stephan (1996) highlighted that geographical proximity matters when knowledge spillovers are informal. When knowledge is transmitted through formal ties, however, between researchers and firms, geographic proximity is not necessary, since face-to-face meetings do not occur by chance but instead it is carefully planned.

Several studies have been conducted to study regional agglomerations, and their economic impact in the areas they flourish in. Those studies highlighted the importance of clustering to foster innovation both on the firm, and regional levels.

Both qualitative and quantitative approaches were used to understand the clustering phenomenon. Two main features generally affect performance of firms located in a certain cluster. *First,* agglomeration externalities that correspond to advantages gained from locating in a cluster. S*econd,* congestion externalities that correspond to disadvantages affecting firms' performance (Beaudry, 2001). Advantages or benefits of industrial agglomeration (or clustering) are divided on both supply and demand sides.

On the demand side, advantages occur from the following factors:

a- Firms located in a certain cluster benefit from local demand generated due to the existence of other industries producing the same, or complementary goods;
b- Consumers generating this demand also benefit due to the increasing competition between rivals, and also enjoy a lower search cost;
c- As entry is stimulated, other smaller firms try to enter the cluster with the aim of taking advantage of the benefits offered to other firms;
d- And with the growing number of rivals and client base, new innovative ideas emerge, increasing the cluster innovative product.

On the supply side, advantages occur from the following factors:

a- Specialized suppliers benefit from better prices for intermediate goods used in their manufacturing;

b- Firms located in that cluster will hence enjoy a larger pool of specialized labour;

c- In the case of agglomeration, firms located within will benefit from infrastructure benefits, such as airports, communication infrastructure, motorways and so on;

d- Knowledge spillovers are also a key supply side advantage, where knowledge is easily transmitted in both its tacit and explicit forms due to the proximity of firms. It is worth mentioning that explicit knowledge is the one that can be transmitted through books, reports and so on, while tacit knowledge is gained from what Malerba (1992) identified as a type of 'Learning by doing'. Such tacit knowledge cannot be transmitted unless users learn from each other. Both types of knowledge can be facilitated by the means of social or professional networks in the forms of social or professional associations, universities or research centres.

Demand side disadvantages arise due to the increased local competition stimulated by a higher rate of firm entry, and the ensuing congestion results in lower pricing, and hence lower profits. This decrease in profitability might lead to high exit rates, as well as lower level of R&D investment, finally resulting into a poor innovative output.

On the supply side, the disadvantages of clustering are also due to the increased congestion. For instance an increase in the number of firms in a certain location will finally increase real estate rentals, salaries and wages for employees.

When studying entry, growth and patenting in the UK aerospace industry, Beaudry (2001) found three general results: *First*, firms located in the same regional boundaries, and belonging to the same sector grow faster then average; *Second*, firms in other industries located with those firms do not benefit from the agglomeration, but suffer the congestion costs that affect their growth. T*hird*, patenting activities are significantly affected by firms' own sector employment, but not from employment of other sectors located in the same cluster.

In their study of the manufacturing industry in UK, Baptista and Swann (1997) asked the question of whether firms in clusters innovate more or less. The main finding was that, on the one hand, firms' innovative activities increase if employment in its sector of production is strong, on the other hand, the effect of employment in other industries does not appear to be significant in showing that congestion effects are the reason of diminishing the benefits that come from diversification within cluster. (However the authors mentioned that limited data made the conclusion a bit inaccurate).

In the same vein, Beaudry and Breschi (2000) examined the relation between clustering and innovative capacity of firms. This study at the firm level in both UK and Italy has shown that, on the one hand, clustering is not the main reason why firms innovate; on the other hand, the resultant innovative capacity grows significantly with the increasing density of innovative firms in that cluster. They also found that non-innovative firms affected significantly the resultant innovative product of the cluster. Beaudry and Breschi (2000) concluded that the correlation between the densities of innovative firms, and the aggregate innovative product is due to knowledge externalities that flow positively between innovative firms.

In their analysis comparing the US computing and biotechnology industrial clusters, Swann and Prevezer (1996) investigated the emergence dynamics of those industries. The main question posed was whether new firms were attracted to industry strength or to the science base strength. Growth of incumbent firms in both industries was studied in order to understand whether the associated growth was cluster-strength dependent or not. On the entry side, it was found that in the computing industry cross-sectoral effects promoted entry, while in the biotechnology industry effects were negligible. This is due to the different structure of both industries, where on the one hand, the computing industry included different but interdependent sub-industries (like component, software, peripherals), which depend on one another to offer computing services to end-users. This creates a positive feedback for all sectors in a given cluster. End user for those different sectors (Demand Side) is quite diversified. For instance, computing services address different types of users like financial institutions, military and normal users. On the other hand the biotechnology industry holds similar technology outlines for different sub-sectors, implying a less diversified industry (especially in the early days) even though applications are different. On the growth side, it was found that the main promoter of growth in both industries is the strength of employment in the firm's own sector, while strength in other sectors or in the science base did not have much significance.

Baptista and Swann (1998) investigated whether firms in the UK manufacturing industries innovate more or not. It was found that a firms' likelihood to innovate is significant if employment in its own sector is strong. Researchers related that to the existence of location externalities associated with industrial agglomeration, where technological knowledge spillovers are a key factor supporting the development of industrial clusters. Another finding of this study is that firms' innovative capacity was not affected by employment or proximity of firms in other sectors. Therefore, firms' innovative activities are mainly fostered by the strength of the cluster to which it belongs, rather then the strength of demand, leading to the conclusion that innovation, growth as well as entry are significantly enhanced when locating in strong clusters.

On examining patents[1] as a mean to appropriate the returns from industrial research and development, Levin *et al.* (1987) demonstrated that when there are some benefits occurring from a certain innovation, competitors tend to imitate, then follow with

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[1] A patent is a perfect appropriability tool that serves to protect the innovator, by imposing a monopoly on the invention for a limited time that ensures the spread of benefits rising from that invention when the patent expires.

incremental innovations to attract new customers and gain market share. It is worth mentioning that there are several methodologies to protect innovations, and thus firms' competitive advantage, such as the use of patents to prevent duplication, secure royalty income, secrecy, market lead time, or other techniques based on sales or services efforts. In their questionnaire targeting the manufacturing industry, Levin *et al.* (1987), discovered that biotechnology and semiconductors are the main two industries that depend on patenting to protect their innovations.

On the R&D side, Rosenberg *et al.* (1994) analyzed the strength and limitation of university research. They argue that university research is mainly directed towards basic research, engineering and problem solving oriented sciences. They demonstrated that universities' main research is directed towards long term problem solving while industry oriented research is more towards short term R&D with a quick return on investment. The above analysis was applied to factors such as the average years of formal education in US, UK, France, Germany and Netherlands, the percentage of R&D that is supported by different entities, whether governmental, academic spending, total engineering spending, as well as total science and engineering spending.

Another aspect studied by economists is *knowledge spillovers,* which is defined by DeBondt (1996) as an "involuntary leakage or voluntary exchange of useful technological information". Theories of Marshall-Arrow-Romer, Porter and Jacobs found that knowledge spillovers generate economic growth, and also that it occurs between industries rather than within them. Other studies demonstrated that localized technological externalities and spillovers have significant effects on regional trade performance (Breschi and Palma, 1998). The study conducted by Breschi and Palma (1998) on different Italian sectors[2] demonstrated that knowledge spillovers affected positively the industrial automation trade, while no effects appeared in other electronics

[2] The study included, pharmaceuticals, plastics, chemicals, industrial automation, office machines, Electronics, control instruments and optical instruments

sectors. The study showed that adjacent provinces' innovative activities affected significantly the trade performance of both provinces. However this strength is different between industries, where technological externalities seemed to be more important in instrumentation and industrial automation sectors. In the Italian electronics sectors no evidence was found of any localized technological knowledge spillovers.

On the spatial dimension, innovative activities and trade emerged within the boundaries of isolated provinces. Therefore adjacency of provinces had no effect on trade performances. In the same vein, Breschi (1998) has studied several manufacturing sectors in Italy and concluded that innovative activities are more concentrated spatially than production, and that the patterns of innovation is spatially different across sectors. For example, he found that the degree of concentration was lower in mechanical and industrial equipment while it was higher in electronics and chemicals. It was also found that industries such as electronics and chemicals were surrounded by non-innovative provinces. Agglomeration economies and localized knowledge spillovers affected positively provinces' innovative performance, while congestion costs affected negatively the numbers of patented innovations.

On the mutual effects between clustering and the competitive advantage of nations, Porter (1990) analysed international trade and explained that the clustering mechanism is a way that increases knowledge and information flow between firms. Furthermore, Porter (1998) has introduced his classical 'Porter's Diamond' (illustrated in figure 1.1) in which he introduced the sources of locational competitive advantage.

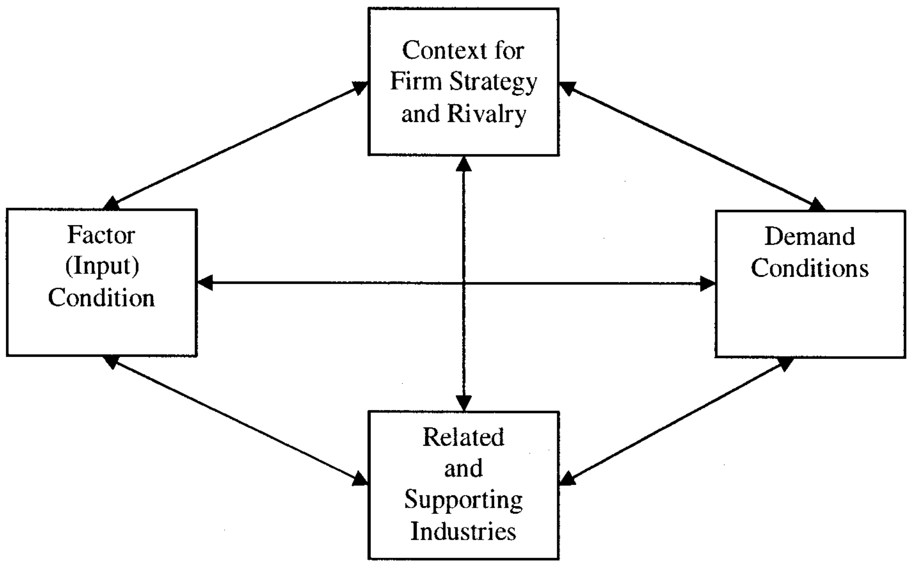

Figure 1.1 Porter's Diamond

As seen, the diamond is composed of 4 building blocks. First is the *factor condition*, which holds everything, related to inputs, such as assets, infrastructure and knowledge base. Second, is the *context for firm strategy and rivalry*, which refers to market rules that control competition between rivalries. Such rules could be for example incentives to produce or innovate. Third, *related and supporting industries* relate to suppliers that provide the studied industries with the required goods and services to manufacturers. Fourth, *demand conditions* that refer to the quality of demand, whether product or process, differentiated or specialized one as explained by Nesta, *et al.* (2003).

Feldman and Audretsch (1999) used knowledge spillovers and innovation as a measurement to examine specialization or diversity of economic activities, and whether it promotes technological change and economic growth. They reached the conclusion that complementary economic activities that are diverse, and share a common science base produce more innovation then a specialized cluster.

Krugman (1991) stated that measuring knowledge spillovers is almost impossible, since it cannot be tracked nor measured. Jaffe *et al.* (1993) however had another opinion, arguing that knowledge can be measured in terms of patents and new products introduction, and that "knowledge flows sometimes do have a paper trail". Jaffe *et al.* (1993) reached the conclusion that on the one hand, specialization does not promote innovative output, and on the other hand sharing a common science base does promote the introduction of new products. They also found that local competition for new ideas within a city leads to more innovative activity than monopoly. The last finding states that greater returns on R&D are obtained by diversity across complementary industries that share a common science base.

Clustering is a global worldwide phenomenon. Saxenian (1994) studied Silicon Valley, which is recognized as one of the most important hi-tech clusters. Bernard (2001) and Athreye (2000) studied the Cambridge high technology cluster in the UK. The importance of the telecommunication equipment industry resides in its product (telecommunication equipment): it is one of the main factors extending the benefits of clustering to unlimited boundaries through unlimited ways of communication with an immense decrease in cost. For instance Eng (2004) studied the implications of the Internet, knowledge formation and diffusion in high technology clusters, and found that the Internet has immensely extended the power of spatial clustering and its innovation outcome.

Bender, *et al.* (2002) investigated whether clusters mattered in Germany's "Neuer Markt" particularly for the telecommunications, technology, software, health care, media, IT services, Internet and biotechnology industries. They examined whether location choice were of importance for enterprises. They found that for bigger firms, clusters matter, however they also found negative effect on those firms' performances, which contradict the theoretical literature proving the positive effects of clustering. Their main findings in the investigated sectors are that lower performing firms are attracted to clusters in order to benefit from externalities, such as local knowledge spillovers of successful firms. In their study, researchers used financial accounting ratios in order to evaluate firms' performance.

Bonte (2003) studied innovation and the impact of agglomeration forces on firm's performance in the German industrial aeronautical clusters. It has been found that recruitment of employees coming from other firms highly depended on the proximity aspect between firms in the German aeronautic industry. Therefore on the labor side, those investigated firms relied heavily on an intra-regional labor pooling rather than on inter-regional migrations. Intra-regional pooling affected positively firms' employment. When recruiting, it was found that firms in the cluster relied more on the labor pool of suppliers and other firms rather than on competition. Bonte (2003) demonstrated that proximity affected firms' product innovation performances while process innovation was not affected. Firms, who hold a higher performance on the product innovation side, were those rating knowledge flow from scientific and public information sources as the most important. Competition (rivalry) does not affect positively the innovative performance of those firms while customer demand did stimulate a positive one. And finally proximity did matter, and did actually affect the innovation capacity of those firms.

Yamawaki (2002) has studied the evolution and structure of the Japanese industrial clusters. For each of the industries studied the number of clusters, average cluster size, and average size by industry was examined. Several sources of Japanese clusters advantages were studied such as: ease of procurement, access to labor market, availability of skilled labor, competitive environment and other cluster-related variables. His research shows that several factors contributed to Japan's cluster emergence; those factors include: historical circumstances, geography, transportation cost and technology transfer. It is stated that the advantages of location in clusters depend mainly on specialized suppliers, as well as on an organized market structure facilitating the flow of knowledge between firms. Japanese clusters benefit mainly from the way firms are organized in a certain location as well as from local governmental support. The cluster organization is represented for example by the way sub-contracting is used; this hierarchy may include multiple layers of suppliers servicing main suppliers, a low turnover rate where skilled employees prefer to stay in the same firm offering a low level of mobility among firms. Communication initiated by government, wholesalers, trade and business associations also is a key player that distinguishes Japanese clusters from other US based clusters. Japanese clusters benefit from the high number of suppliers in localized industries. Supplier's skills, capacities and know-hows complement manufacturers developing competent advantageous industrial clusters.

Other researchers focused on the emerging software clusters in Ireland, Arora *et al.* (2000) showed that low average age of Irish population has contributed positively to the Irish software industry. Other factors that affected clustering is the quality of commercial and physical infrastructure. They found that the Dublin area suffered from congestion as well as from great pressure on its infrastructure quality. The software cluster suffered also shortage of skilled labor. While smaller firms suffered from managerial skills, larger firms were seeking international markets to survive. Not much link between the software industry and research centers or universities is established, even though the majority of employees of those firms came from Irish Engineering schools. It was also found that MNCs played a key role in fostering software R&D

activities in Ireland and were the main source of knowledge spillovers in those industries.

1.3 Studies of Canadian Clusters

The impact of the so-called Internet bubble boom and burst and its impact on the Canadian market structure were studied by Beckstead & Brown (2005). In their study on the Canadian ICT (Information and communication technology) sector they showed that there is little evidence of structural shift in this ICT sector. They show that the ICT sector did not suffer much compared to other sectors in the economy and demonstrated that entry rates were above that of other sectors. The key explanation for this phenomenon is that entrepreneurs continued to see opportunities to develop new products and new markets for those products. They show that the high entry and exit rates were due to the fact that in the ICT sector, some products are still in their early stages of their life cycle, hence the high turnover that the industry is witnessing due to experimentation. In addition, they found that big Canadian cities (Montreal, Vancouver, Ottawa & Toronto) attracted the majority of firms.

It is worth mentioning that the telecommunication industry is a high technology industry that is extremely dynamic, and introduces a tremendous amount of innovations. Innovations in the telecommunication industry comprise 2 types of innovations (Bourreau & Dogan, 2000): innovations for new services provided by telecommunication operators and service providers, as well as network and infrastructure innovations provided by the telecommunication equipment manufacturers. The later is the subject of our study here.

On the Canadian level several researchers investigated the cluster phenomena. None of these researchers addresses to our knowledge the telecommunication equipment industry. Several researchers studied other high-technology industries such as biotechnology; see for example, Aharonson, *et al.* (2004) who investigated the Canadian biotech industry, and the return from its inventive activities. They showed that clustered firms are eight times more innovative then firms outside the cluster. The clusters that attracted those biotechnology firms are ones that were strong in those firms main specialization. It was also proved that R&D alliances between firms locating in the cluster, increased firms innovative production, and that knowledge spillovers produced by those firms is directly correlated with their spatial locations. Spatial concentrations were measured by the use of postal address codes.

Mohnen and Therrien (2002) compared the innovative performance of Canadian firms and some selected European countries. The study was conducted using European and Canadian Innovation Surveys, and demonstrated that Canada holds a higher percentage of innovative firms. Sales generated from these innovations however are not correlated with the innovative capacity of those firms. The study showed that Canada is more innovative than France, Germany, Ireland and Spain put together. The researchers showed that their results could contain some errors, for example the definition of innovation in both surveys could be different. The questions in the survey may convey different interpretations to what innovative means, and to the measurement of its order of magnitude.

Niosi (2002) has also conducted several studies targeting different industrial sectors in Canada. Niosi (2002) explained the rapid growth of hi-tech industries like the Canadian biotechnology industry. Niosi showed that exploring international markets for Canadian firms was crucial to ensure rapid growth. Fast growing firms patented extensively in that sector, and used venture capital strategies to finance their R&Ds. It was highlighted that alliances are quite important in that sector. On the one hand, if new firms with new ideas went through alliances too early they face the risk of losing most of the innovation benefits. On the other hand, if they form alliances too late firms risk running into financial problems. As a general conclusion, Niosi demonstrates that networks and alliances are not the main factors that lead to growth. He highlighted that start-ups use universities research centers and government laboratories at the beginning, but the main success factor is the use of venture capitalists, and large partners to sustain elevated growth rates.

Niosi and Zhegu (2002) investigated the cluster phenomenon in the aerospace industry within Canada in the regions of Montreal and Toronto, and also compared Canada as a whole with international famous aerospace clusters namely Toulouse and Seattle. The study used regional employment between regions, jobs allocated in major North American cities, and the patents per cities and companies as indicators. The study showed that large firms dominate aerospace clusters. Due to the international nature of this industry, the researchers highlighted that the role of local demand and local inter-firm competition is marginal. SMEs are therefore not attracted to the region, however several spin-offs have been monitored serving large firms' in order to increase their competitive advantage and core competencies. Suppliers were attracted to the region but diversified their production to minimize risk. In that particular industry, products could be designed in a location and produced in another. The role of universities and government is marginal in that industry, and indeed aerospace university graduate programs and research in Montreal were created a long time after the creation of its industrial structure.

1.4 Entry and Exit Analysis

'Market structure' is one of the main topics of the Industrial Organization field. One of the key areas of studies that determine the shape of market structure is firm creation, exit or mergers (Carlton and Perloff, 1989). Firm creation due to mergers takes one of three forms: First, *horizontal mergers,* where there are transactions between competitors; Second, v*ertical mergers*, where firms that produce for each other are merged; and finally c*onglomerate mergers,* where firms in unrelated businesses merge. Mergers and

Acquisitions (M&A) is an important method of acquiring new products or technologies. Companies such as Cisco regularly used M&As to acquire new technologies too expensive to develop in-house. In fact, high-technology firms in the communication equipment industries such as Nortel Networks, Lucent and others commonly use such a strategy. However Cisco is one of the companies that depended the most on M&As, from 1993 to 2001, Cisco acquired 71 firms (Paulson, 2001).

In the field of Industrial Organization, exit and entry analysis is one of the key determinants of industry concentration. The entry and exit rates depend on the success of 'barriers to entry'. Generally speaking, barriers to entry are whatever obstacles in place that prevent firms from entering a certain market. Economists identify 2 types of barriers to entry: short run and long run barriers to entry. Long-run barriers are what make incumbent firms achieve long-run profits while at the same time preventing new-entrants from entering a specific market or industry. Long-run barriers have the greatest effect on market structure and hence on concentration. Barriers to entry as explained by Bain (1956) take one of three forms: First, *absolute cost advantage* occurs when an incumbent firm is able to produce at a lower cost level than others, then it can definitely increase its profit with a margin that does not exceed the other firms' cost and still can enjoy protection from entry; Second, incumbent firms usually enjoy *economies of scale* that new entrants might not be able to benefit from; Third, is the *product differentiation* where incumbent firms enjoy highly differentiated products which might constitute a barrier to entry for new entrants. It is important to note that the later case might not be true if new entrant firms also hold such a highly differentiated product and enter the market using first-mover advantage, bearing in mind that they can afford marketing costs till product is marketed and profits earned.

The above-described modes of entry and exit generally constitute the field of *Industrial Dynamics*. Another emerging field of research is *Knowledge Dynamics,* in which knowledge shapes the form and the evolution of industrial clusters. For example, Krafft

(2004) proposed the development of the 'knowledge based industrial dynamics' approach to explain how a cluster decreases barriers to entry between clustered firms and creates its own proprietary knowledge dynamics that changes the clusters' industrial dynamics. Furthermore this study has been applied empirically to the telecommunication equipment (or so called info-communication) manufacturers in France. The study shows that knowledge dynamics decrease barriers to entry, and that these dynamics are not based on the cluster itself, rather they are the result of interaction between firms and research centers that leads to new entries and decreases the exit rate of firms in the French telecommunication equipment manufacturer's cluster.

Industry shakeout is the phenomenon that describes the sharp and rapid fall of firms in a particular industry, and is explained primarily by three main factors: entry, exit and innovation. When studying industry shakeouts and technological change, Klepper and Simons (2004) examined four US industries that suffered a sever decline in the number of entrants, and a higher exit rate. The four product oriented industries are that of automobiles, televisions, tires and penicillin. Using hazard analysis they have showed that early entrants have the lower hazard in the shakeouts, and they explained that this is due to the great numbers of innovations of these companies. These innovative companies enjoyed a 'rich-get-richer' dynamics, where their privileged incumbent position made other smaller entrants and innovators with less ability to cease from entering the market. They also found that shakeouts are not initiated by technology or other related events, but that they are triggered by a severe competition period during which early entrants are dominating through innovation. In studying the properties of those shakeouts, it was demonstrated that shakeouts often occurred in highly concentrated markets.

Klepper and Simons (2004) state that there are three theories of industry shakeouts that feature innovation. First, the *radical invention theory* developed by Jovanovic and MacDonald (1994), stating that a radically new invention builds a new industry. In that case, firms who can produce that invention rush into that industry until profits erode to zero. With time, innovators who failed to adapt or produce exit the industry, and the shakeout ends when all unsuccessful innovators exit the market. Second, the *dominant design theory* developed by Utterback and Suarez (1993), stating that a dominant design dominates the industry and entry becomes difficult. Companies with the desire to enter the market move into process innovation to produce the same product but with the lowest cost possible. With the low entry rate, a shakeout occurs when all unsuccessful firms and innovators start quitting. This shakeout does not stop unless all unsuccessful firms and innovators are out of business. The third and final theory is the one developed by Klepper (2002) known as the *competitive advantage theory* where industry innovation and market structure co-evolve. In that theory, firms with higher R&D capabilities enter the market. As entry rate increases with highly capable R&D spending firms, industry product (output) grows and prices fall. In that case only entrants with higher R&D ability enter to gain profits. At a certain time, even firms with a high R&D ability cannot enter profitably and therefore entry stops. With the severe decrease in prices, and the erosion of profits, unsuccessful firms and innovators exit, and an industry shakeout occurs until only the earliest entrants, who are highly capable, are dominant.

Audrestch *et al.* (1997) demonstrated that both firm and industry characteristics affect firms' survival during the first years after entry. However, moving from the short run to long run, firms' characteristics are the main factors affecting survival rates, while industry characteristics effects diminish. It is worth noting that industry characteristics include factors such as the relative importance of innovation, technological change, capital related measures, while firm characteristics include firm's start-up size, capital intensity, and debt.

As Fauchart & Keilbach (2002), several researchers tried to discover the relationship between market structure and innovation, and discovered that innovation influences market structure. This result is supported by Audretsch (1991), Baldwin (1995), and

Breschi *et al.* (2000), who found that the technological regime that dominates the industry affects the relation between innovation and market structure. It is worth to note that 'technological regime' is defined as Nelson and Winter (1982) put it as "a combination of technological opportunities, technical knowledge accumulation, appropriability and protection of innovations and finally the knowledge base affecting the firm's capacity to innovate".

Also on the role of firm's entry, exit and survival, Audretsch (1995) has demonstrated that innovation is the key factor that stimulates the evolutionary process of markets. It is worth mentioning that inputs that finally lead to innovative output are a product of accumulated knowledge within the firm, as well as of technological regimes, both of which are different from one industry to another. In his research Audretsch (1995) based his analysis on the longitudinal databases that identified start-ups of new firms, and their performance. The basic question that Audretsch (1995) asks is "Why do economic agents start new firms?" rather then "Why do firms enter an industry?" and the answer is: "If economic knowledge diverges across decision makers, incentives are higher to start new firms". In most cases, new start-ups suffer cost disadvantages due to lack of capital but they usually manage to survive by using compensating factor differentials. Audretsch (1995) also found that the structure of current industries is characterized by a high degree of fluidity and turbulence and that what shapes the evolution of firms are the knowledge conditions influencing innovative activity. According to Audretsch (1995), measures of technological change include three major aspects of innovative process: first, is the measure of inputs such as R&D expenditures, or the share of labor force involved in R&D activities; second, is the intermediate outputs such as the number of patents; and third, is the direct measure of innovative outputs, which is handled through the knowledge regarding the determinants and the impact of technological change.

It should be evident that, on the one hand if R&D is used to measure innovation, we are actually measuring input rather than outputs. On the other hand, the use of patents as measure of innovation output according to Audretsch (1995) does not address the economic value of this innovation. It is worth noting that innovation is a process that begins with an invention, and is followed through with the development of the invention that finally results in the introduction of a new product, process or service to the market place. Not only do patents not hold economic value but also it is important to mention that most patented inventions do not lead to innovations. Also not all innovations are patented. It was found that the value and cost of individual patents vary within and across industry; therefore using patents as a measure of innovation is severely challenged since it does not reflect the actual image of industrial innovation. Schumpeter (1939) explains that an innovation is the result of new economic knowledge embodied in an individual. According to Schumpeter, entrepreneurs exploit an invention to produce a new product or produce an old one in a new way. Such a way of thinking obliges the entrepreneur to think in a different way than anybody else. Due to the importance of knowledge, Audretsch (1995) explains that new-firm start-ups are shaped by the knowledge conditions of the industry being studied. Therefore, on the one hand, the more routinized is the technological regime affecting an industry, the less start-up activities are monitored. On the other hand, in industries subject to entrepreneurial technological regime, new firm start-ups play a more important role.

When trying to investigate the relation between innovation, growth and firms' survival, Audretsch (1995) discovered why firm survival rates vary from industry to industry. The researcher demonstrates that the higher innovative activities are in some industry, the higher is the likelihood of survival of new entrants. On the one hand, he explains that if new firms are able to adjust and offer a viable product experience, then they witness a high rate of growth as well as a greater likelihood of survival. On the other hand, entrants and certainly new firms that are not able to adjust and produce a viable product face lower likelihood of survival in such innovative environment. It was also demonstrated that scale economies and product differentiation are considered barriers to survival of the new firms. These barriers to entry decrease with time and new firms are getting more and more adaptive to them. One of the strategic moves new entrants use is trying to differentiate their products through innovative activities, this compensates to some extent for scale disadvantages. It is interesting to note that if firms managed to survive through innovative activities, those activities will serve as a barrier to survival for newer entrants within the first few years after their entry.

As a conclusion, firms who innovate, differentiate their products and are able to adapt to changes are able to survive and grow in a way that compensates for the scale and other size related disadvantages that incumbent firms enjoy. Also on entry, Baptista and Swann (1996), when studying the computer industries, in both UK and US, found that strong clusters generally attract new entrants, and that firms in strong clusters tend to grow faster.

1.5 Literature Review Summary and Research Hypothesis

From the above literature we can see that proximity matters primarily to establish formal ties (Audretsch and Stephan, 1996). Those formal ties together the increase in the density of innovative firms in a certain cluster produces knowledge externalities flowing positively between innovative firms (Beaudry and Breschi, 2000) improving the cluster's resultant innovative capacity. At the cluster birth phase, firms start to rush into a certain cluster to benefit from knowledge externalities. With time, the cluster starts to grow, congestion externalities increase and the cluster starts to saturate. After a while, congestion externalities rises aggressively and entry rate starts to fall sharply, while exit rates starts to dramatically increase till no new firms enter the cluster, and only old firms capable of surviving in their own cluster remain active (Swann, 1998).

Firms that enter a certain cluster could be producing complementary or substitute goods or technologies. It has been noticed that clusters that hold a diversified set of economic activities and cross-sectoral structure promote entry in the US computing industry

(Swann and Prevezer, 1996). In the same vein, Feldman and Audretsch (1999) proved that this diversity, when sharing a common science base leads to a more innovative cluster than a specialized one. This diversity across complementary industries has been proven to hold greater returns on R&D (Jaffe et al., 1993).

When examining the role of universities, we can understand that in general universities are directed towards long term problem solving, while industry focuses on short term R&D with a quick return on investment (Rosenberg et al., 1994). This correlates quite well with the finding of Niosi and Zhegu (2002) who found that the role of universities and government is marginal in the Canadian aerospace sector, and that in fact graduate research programs in Montréal were created long time after the creation of its industrial structure (Niosi and Zhegu , 2002). This of course is due to the dominance of large firms in the aerospace cluster and to its international nature, where the role of local demand and local inter-firm competition is marginal (Niosi and Zhegu, 2002). This industry structure that characterizes the Canadian Aerospace industry examined by Niosi and Zhegu (2002) is primarily due to the fact that the Aerospace industry is an old one (that dates almost a decade). Early entrants in such industries had lower hazard in any technological or economic shakeout due to the great number of innovations these firms produced. Among these incumbent firms, innovative ones enjoyed a 'Rich get Richer' dynamics while other smaller entrants and innovators with less financial or technological ability to cease from entering the market (Klepper and Simons, 2004)

Last but not least, Beckstead & Brown (2005) did not find evidence of any structural shift in the ICT sector subsequent to the IBBB. This finding triggered us to examine if this remains true in the Telecommunication Equipment sub sector of the ICT or not.

1.6 Conclusion

As seen in this chapter, several researchers from different backgrounds have contributed to the study of industrial clusters. The diversity of research in that domain has made the literature quite rich. The richness this diversification offers extends from geography to methodologies used. For instance, it was noticed, that researchers studied clusters from different regions namely, Europe, US, Canada and Asia. The research methodologies varied accordingly. While some are quantitatively oriented (Beaudry, Breschi and others), others tend to be more qualitative like Saxienian and Athreye. Besides the quantitative approach mainly based on econometric models and qualitative studies mainly based on interviews, others used simulation to study the evolution of industries. Not only do the methodologies depend on the researcher's background and the problematic being studied, but also on the availability of data. The literature review presented also focused on the structural changes and shakeouts that occur in the market place, in the form of firms' entry, exit, mergers and acquisitions. Such literature from the industrial organization field will be quite useful when studying the Canadian telecommunication equipment market after the downturn of 2001. It has been noticed that Canadian researchers mainly focused their efforts on high technology industries; however none of them tackled the Canadian telecommunication equipment industry specifically. When trying to understand the Canadian innovative capacity, researchers mainly focused on the general manufacturing industries, or generally the ICT sector.

CHAPTER 2 – TELECOMMUNICATION EQUIPMENT TECHNOLOGY OVERVIEW

The aim of this chapter is to understand the dynamics of the telecommunication equipment industry. In order to achieve this, the chapter is divided into 3 parts: section 2.1 introduces the communication industry's history. Section 2.2 highlights the current telecommunication industry trends. Section 2.3 introduces the Canadian Telecommunication Equipment Industry and finally section 2.4 concludes.

2.1 General History

The Webster dictionary explains the Latin root of "communicate" as "communicare" (McPhail, 1986), which means to share or to make common. Nowadays, communication is about transmitting information or messages. Telecommunication is about transferring information (whether data, voice or video) over a distance. Communication systems started a long time ago, from the days of ancient Greeks, fire was used to signal messages between troops. In the beginning of the 17th century, the telescope was invented and in the year 1664, Robert Hooke proposed transmitting messages by putting them on display areas to be read by telescopes, hence reducing the number of stations needed to transmit messages (Solymar, 1999).

Then in the year 1794, Claude Chappe invented the mechanical telegraph. The mechanical telegraph was composed of 2 major components, the regulator and the indicator, the variation of these positions composed letters that could be decoded with the change of the positions of the 2 rods, and later encoded by book with the receiver to finally understand the information. In 1796 Lord George Murray invented the shutter telegraph, which was composed of shutters that flip-flop transmitting information in a binary form. Those telegraphs were used in UK to connect London with principal ports and later were commercialized in Liverpool specially to establish communication between ship owners and merchants.

In 1837 Samuel Morse introduced the electric telegraph. Morse was a painter and an artist who excelled at painting portraits, however he had interests in electromagnetism therefore he attended lectures at the university. Morse code is his main invention; alphabetical letters are represented by dots and dashes transmitted over telegraph systems, such as the needle telegraph. Morse code continued to be used until 1993 (Bray, 2003). The power of Morse code is that it assigned the shortest representation to letters that are more frequently used; therefore the code was optimal to transmit large complex messages. After the introduction of the breakthrough Morse telegraph, several incremental innovations followed such as the printing telegraph invented by David Edward Hughes.

In year 1874 a brilliant telegraph operator called Thomas Edison improved significantly the telegraph with patents that enabled the telegraph to simultaneously transmit 4 messages on the same wire. Then came Baudot, who in 1874 used coding to transmit alphabet using 5 elements, Baudot developed the seed of what is currently known as pulse-code modulation, and modern digital techniques (Bray, 2003). The UK was the first to use telegraph using under-sea cables, mainly for diplomatic purposes. In 1866 the first trans-Atlantic telegraph message was sent between the UK and USA.

Probably the most important among different communication equipment is the telephone. Alexander Graham Bell was born in year 1847 in Edinburgh. Bell's father and grandfather had interests in vocals in speech, an interest that was naturally nurtured in the young Bell, who later became a professor of vocal Physiology at Boston University. Bell was mainly interested in teaching the deaf how to improve their speech. Based on that, Bell got interested into transmitting voice by electricity. In year 1876, Bell was granted his first patent number 174,465 for the telephone using a transmitter, a receiver and a coil with a battery to transmit sound waves using electromagnetism.

Several inventors claimed to have invented the phone, it is said to exist more than 800 law suits in the US courts (Oslin, 1992). Those inventors included Meucci from Italy, Bourseul from France, Reis from Germany, Elisha Gray and Thomas Edison from the USA. Telephone was used to transmit voice from one point to another. With the growing number of telephones connected from point to point, switches with operators were put in place to provide switching between different locations. In year 1889, Almon Brown Strowger was annoyed by the lack of privacy, where human operators had full control over phone calls, so he invented what is called the automatic telephone switching system named after his name the 'Strowger Switch', that Strowger called 'the girl-less, cuss-less telephone'!

With the growing number of nodes, and telephones, telephone automatic switches became indispensable. The use of Strowger switches continued to be used until the 1970s. Western Electric (later Northern Telecom and Nortel) the manufacturing arm of Bell was responsible for manufacturing these switches. With the introduction of radio waves, Fleming, a British researcher and an electrical engineer designed, together with Marconi, the first transmitter of radio waves across the Atlantic in 1901. Of course such a breakthrough was supported by the rich scientific theoretical work provided by Maxwell and Hertz on electromagnetic radio waves. The first patent for wireless telegraphy (British patent No 12039) was awarded to Marconi on 1897.

As seen in the beginning of the 20th century all innovations were based on individual inventors. Inventors like Bell, Morse, Marconi and others were individuals who had innovative ideas, based on which they implemented communication systems. These entrepreneurs are said to have had a maximum of 10 to 20 assistants (Flishy, 1995).

But after the telecommunication industry's evolution and the rapid increase in the number of subscribers together with the global dimension of communication, it became clear that more capital was needed to generate more sophisticated systems. And thus began the era of R&D, in which R&D played a key role in defining the new leader in the telecommunication sector.

In the telecommunication equipment industry of it is forecasted that eventually, data, voice and video will converge. The use of packet switching will become the standard way of communicating. Major vendors such as Cisco, Nortel and others are capitalizing on this strategic opportunity. While a company like Cisco was capitalizing on its expertise in data communication, established companies like Nortel did not see at the time that network convergence had reached its mature phase to be commercialised just yet. For example in 2000, Nortel's CEO John Roth presented the vision known as the 'Webtone' which assures that eventually networks will converge, but not just yet and that the quality offered by data network to transmit high quality packet streamed data is still in its beginning (MacDonald, 2000).

Roth (Nortel's CEO) announced his vision of leading network convergence using advanced technologies that will lead to a standard as high as the one used with telephony, and voice systems. Between these leading firms technological strategic wars began to take place. For example, leader firms in the telecommunication equipment industry sometimes used co-opetition strategies in order to maximize their profits and cut down their losses. In 1997, Chambers, Cisco's CEO, approached both Nortel and Lucent to cooperate on building the Internet infrastructure. However, the US Federal Trade Commission (FTC) blocked these negotiations. The problem was that the three companies had similar product lines (MacDonald, 2000) and if one were to exit a certain market, its revenues would decline. As an alternative strategy each of the incumbents equipped itself with a series of acquisitions; for instance, Nortel acquired Bay Network (Cisco's main threat in data communication); Lucent acquired Ascend Communications

(2^{nd} ranked data networking firm worldwide); and finally Cisco acquired Cerent Corp. to get into the fiber-optic segment.

As a consequence of this competition, each of the three incumbents is trying to address the quality of data networks, in order to accommodate quality convergence. Cisco, for example, is working on network management software to make routers more intelligent, using priorities to voice over data to assure quality service. Nortel is working on solutions to combine voice and data on the available networks by redirecting data traffic from the circuit based switching network on data packet overlays. This way, voice is kept on original telephone networks. Nortel's solution is considered as more evolutionary than Cisco's solution (MacDonald, 2000).

It is worth to mention that that using the Internet Protocol (IP) and packet switching to transmit normal data would not affect the quality (except for certain delays), however, when trying to transmit high-quality data such as voice or video, delays can prevent the receiver from obtaining the correct message which is not acceptable when trying to transmit such heavily complex data streams.

It is important to know that rivals, and relatively new entrants (like Cisco as compared to Nortel) mastered the so called 'open standards', where the networking solutions provided by companies like Cisco (and Sun Microsystems in the servers domain) offered interconnection between different platforms (Gawer and Cusumano, 2002). This strategy led by new Silicon Valley rivals opened new markets, and in fact established a new way of producing new technologies. For instance, established firms in the high-technology industry used to protect their platforms with proprietary innovations such as IBM's AS400 mainframe technologies. This strategy gave Cisco the first mover-advantage in the router market when at the same time while incumbents like Nortel, Lucent, Siemens and others arrived late in that particular market.

Nortel launched a price war against Cisco, by reducing the price of routers.[3] On the fiber-optics technology side, Cisco has used its M&A strategy to acquire companies that produce fiber-optics technologies. Nortel and Lucent are also increasing their competitive advantage by investing further in R&D, as well as using strategic acquisitions to further enhance their market position. Indeed 75% of the North American Internet traffic is carried on Nortel fiber-optics products. In addition, on the wireless side, market research groups (like the Yankee Group) rank Nortel as the leader for wireless Internet.

If we take early entrants in the telecommunication equipment manufacturers market (i.e. Nortel, Ericsson, Nokia), it can be seen that all of them managed to survive despite the economic downturns they suffered. Since the current study has main concern the Canadian market, Nortel is in fact a leading example of how incumbent firms managed to evolve and adapt to market and technological changes occurring at the market place. For instance, firms like Nortel understood very well the importance of regularly identifying new opportunities and technologies in the market. John Roth, Nortel CEO's appointed in 1997, was known for his abilities to monitor market changes and industry trends as well as for capitalizing on these changes. And indeed Roth said: "designing it for today, it is designing it through several cycles of technology...and as technology evolves, these components get cheaper, these components get more powerful, the whole design becomes better...as opposed to it becoming obsolete" (Macdonald, 2000).

An example of such a vision could be seen in the way Nortel tackled the wireless market. Nortel's core competency is switching. Classified as a late entrant in the wireless market, relative to early comers like Motorola, Nortel capitalized on its knowledge in switching by entering a joint venture with Motorola, the largest cellular phone manufacturer at the time. Such a vision and adaptability to market changes as well as leading new technologies is quite common for companies such as Nortel and others in

[3] Note that Nortel owned Routers technology after acquiring Bay Networks

trying to adapt to changes in order to survive. Let us review the history of Nortel to demonstrate the point: For example, Nortel went into the satellite business in 1972 when it put its electronic platform in the communications satellite Anik-1. The company introduced digital communication switching in 1975, thus introducing to the market a breakthrough technology that enabled to transmit voice and data over the same wiring infrastructure. In 1989, Nortel managed to provide fiber-optics technologies used into SWIFT used to connect financial institutions globally.

This adaptability can even be seen in the changes in the names of Nortel. In 1882, Nortel started as the mechanical department of Bell Telephone of Canada to manufacture telephone equipment. In 1895, this department was named 'Northern Electric and Manufacturing Company'. In 1914, it was merged with Imperial Wire and Cable Company Limited to form 'Northern Electric Company Limited'. In 1976, again the name changed to 'Northern Telecom', this was done when the company was trying to move into the digital technology, In 1995, the Nortel name was introduced with the creation of the Webtone vision converging data, voice and video on the same networks. Finally in 1999, Nortel Networks is the current legal company name. This evolution of names show how Nortel's priorities changed over time, as well as with technological trends.

On the technology side, Nortel has gone through different eras of technological discontinuities and disruption. Capitalizing on those discontinuities, is one of the key factors based on which Nortel has managed to survive. For example, the switch from analogue to digital technologies, as well as from copper-based transmission to fiber optics, and from wired (or wireline) to wireless communication, are all examples of managing technological change, using innovation both on the product side as well as the marketing side.

Another success story in the data communication business is that of Cisco. Cisco is a clear example of how a small business grows to reach the size of very large enterprises. Cisco was founded year 1984; however the story started in 1979-80 when Sandra Lerner, Leonard Bosack together with Bill Yeager, all Stanford employees developed a router, while working in Stanford University Information technology department. It all began when 'Santa Claus'[4] visited Stanford University introducing Ethernet latest technology (Bunnell, 2000). Stanford University used this technology to connect between Stanford Medical School and the computer science department. Other departments who had other types of minicomputers wanted to get connected too, and this is when Lerner and Bosack had the opportunity to experiment and build a router capable of connecting two different, incompatible local area networks (LANs). The university did not want to support any marketing for the router product, so Lerner and Bosack started their own start-up and named it Cisco (Bunnell, 2000).

After tremendous success from 1984 to 1987, Don Valentine, the founder of Sequoia Capital (a venture capital firm) stepped in with Cisco, and since then, Cisco's business has grown exponentially year after year. This highlights the role of venture capital supporting data communication companies such as Cisco as success factor. Another success factor, as previously highlighted, is the location of Cisco, within Silicon Valley along with its rivals. Bunnell (2000) said, "Cisco not only had its timing right, but its choice of location as well. Silicon Valley, which seems to emanate from the Stanford university campus, was considered a major hub". Aside from location, the timing was also right because in the same years Cisco pushed the router product it was decided to open the ARPANET (Advanced Research Project Agency Network) to the public, enabling users to use what is currently called the Internet. Of course this put extensive demand on routers to connect different networks and users all together. As previously stated, Cisco relied heavily on mergers and acquisitions, to acquire complementary products to their niche ones, in order to provide broad networking solutions.

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[4] A firm selling Ethernet Technology

One main reason for using such a strategy is that Cisco did not have enough R&D resources to keep up with other Internet inventions (Gawer and Cusumano, 2002). An example of such acquisitions is that of Crescendo, the manufacturer of intelligent switches that compete with Cisco's routers yet with a cheaper price.

Deregulation in the telecommunication industry, also played a key role, encouraging incumbents, who had strong protection, to compete with rivals, as well as with new entrants. At the beginning of the 20^{th} century the US government protected the telecommunication industry, in the 1960s began a complete policy change. The classical case was that of the 'Carterfone' decision, where the US federal communication commission (FCC) ruled in favour of an applicant who wanted to attach his own equipment to the public telephone network. This decision opened up new markets for other manufacturers, Nortel for instance, as communication equipment could be leased from other companies than AT&T. In 1971, the FCC allowed telephone networks to be interconnected, opening the market for companies like MCI (Microwave Communication Inc.) to offer long-distance calling services, indicating that other companies from Bell were now able to enter the infrastructure communication equipment market. Also another discontinuity was the famous break-up of AT&T in the 1980s (MacDonald, 2000). This was a huge opportunity for the Canadian supplier, Nortel, to enter aggressively in the US market, which was a monopoly for US suppliers. Nortel benefited from all the above market discontinuities, to further increase its position as a leader in the telecommunication equipment industry.

2.2 The Telecommunication Industry

This section will be divided into two subsections, the first will address the basic telecommunication technology concepts, and the second will address the current telecommunication equipment industry trend.

2.2.1 Telecommunication Technology overview

In order to ensure an efficient, secure communication between different networks protocols were invented. Organizations such as the ITU (International Telecommunication Union) and the IEEE (Institute of Electrical and Electronics Engineers) are responsible to develop such standards. One of the standard reference models used in data communication networks is the 'Open Systems Interconnection' (OSI) reference model. The OSI model as seen in figure 2.1, describes any data network, from transmitting bits over hardwires (physical layer) to receiving those bits on an application to perform a certain task, or just transmitting data to the required destination. Data when transmitted should theoretically pass through each of the seven layers of the OSI reference mode. Each layer has a different task as indicated in its description. First data packets are built, and send over the physical layer (Layer 1), then the data link is established by determining protocols that will be used in the transmission (Layer 2). The data is assembled into packets that hold the data as well as other data switching and routing information (Layer 3). After that, data is transmitted (Layer 4), while connections are controlled (Layer 5), presented (Layer 6) and finally sent to the corresponding application (Layer 7). It is important to know that each protocol can use some layers and ignores some others depending on the type of application, level of security and the type of data transmitted. This is why the OSI is called a reference model.

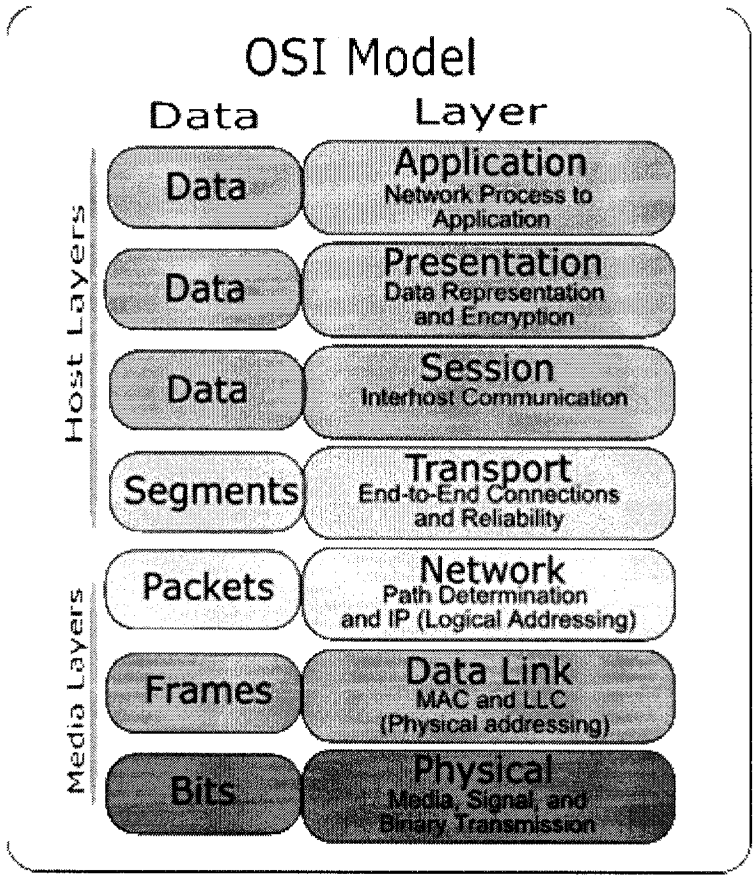

Figure 2.1 OSI Reference Model (By JB Hewitt from Free Software Foundation)

Communication Connections are usually established in one of three ways: - Dedicated circuits, Circuit switching or packet switching. Those technical terms are often used in telecommunication.

First, dedicated circuits (as identified by the name) are circuits that are dedicated and permanent between 2 or more nodes. Enterprises or users who hold heavy traffic between them usually lease these kinds of circuits, and in that case it is more economical to use. An example of dedicated circuits is connections between different bank branches.

S*econd, Circuit Switching* are temporary connections, initiated between the sender and the receiver. The same communication channels are assigned between the sender and the receiver as long as there is a connection. Examples of circuit switching connections are traditional telephone calls.

Finally third, Packet Switching, in that case, information whether it is data, voice or video are transformed into data packets. These data packets can follow different paths, it is therefore much more flexible and intelligent then circuit switching, or dedicated circuits. Each packet holds the address of the destination within its structure, and uses switches and routers to arrive to its final destination. Examples of such connections are internet based connections. Of course each packet might use a different route, hence the name router to designate the device that provides routes for packets. Another important product in communications is the switch. Switches can forward packets to different destinations using 'preset instructions' and predefined packet pathways. Compared to routers, switches are not intelligent since they only work with predefined instructions and rules (Gawer and Cusumano, 2002). Network protocols regulate this kind of transmission. An example of such protocols is the commonly used TCP/IP that stands for Transfer Control Protocol/ Internet Protocol.

Public Switched Telephone Networks (PSTNs) are used for voice communication. It is important to note that voice is an analogue signal. PSTNs were originally analogue networks, both on the transmission as well as on the switching sides of the network. After the recent advances in digital technology, PSTNs were converted to digital networks especially in large and medium sized enterprises. Analogue PSTNs however are still functional in small businesses as well as residential locations (See figure 2.2 below).

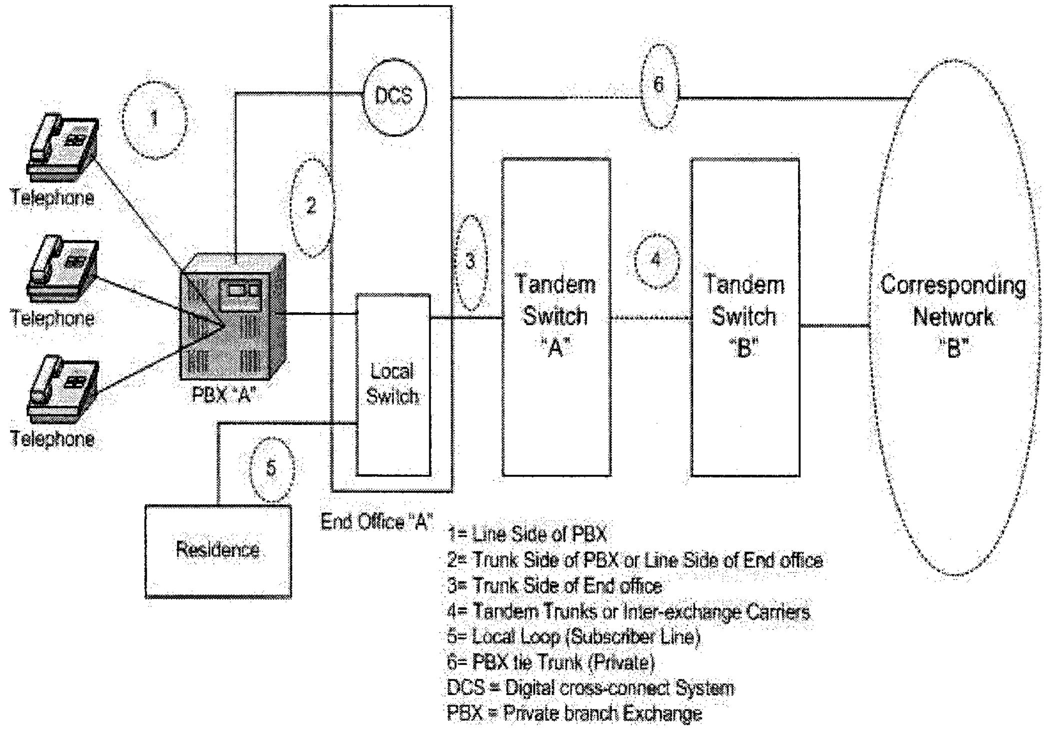

Figure 2.2 PSTN Digital Network (Costello and Horak, 2003)

Simply, when a telephone call is placed, the destination (using the phone number) is switched through the local switch that passes through the tandem switch, which in turns searches for the destination and establishes the connection with the desired phone number. After the two terminals are connected, voice is transmitted between sender and receiver. Here it is important to note that the switching in that network is digital, while the voice itself is transmitted using analogue signals. Therefore, the network is analogue on the transmission side, and digital on the switching side. With the rapid development of digital network, new technologies like VoIP enabled sending voice over data networks, hence the transmission side in that case is digital.

Voice over IP is transmitting voice over the Internet, using packet based switching. (See figure 2.3 below)

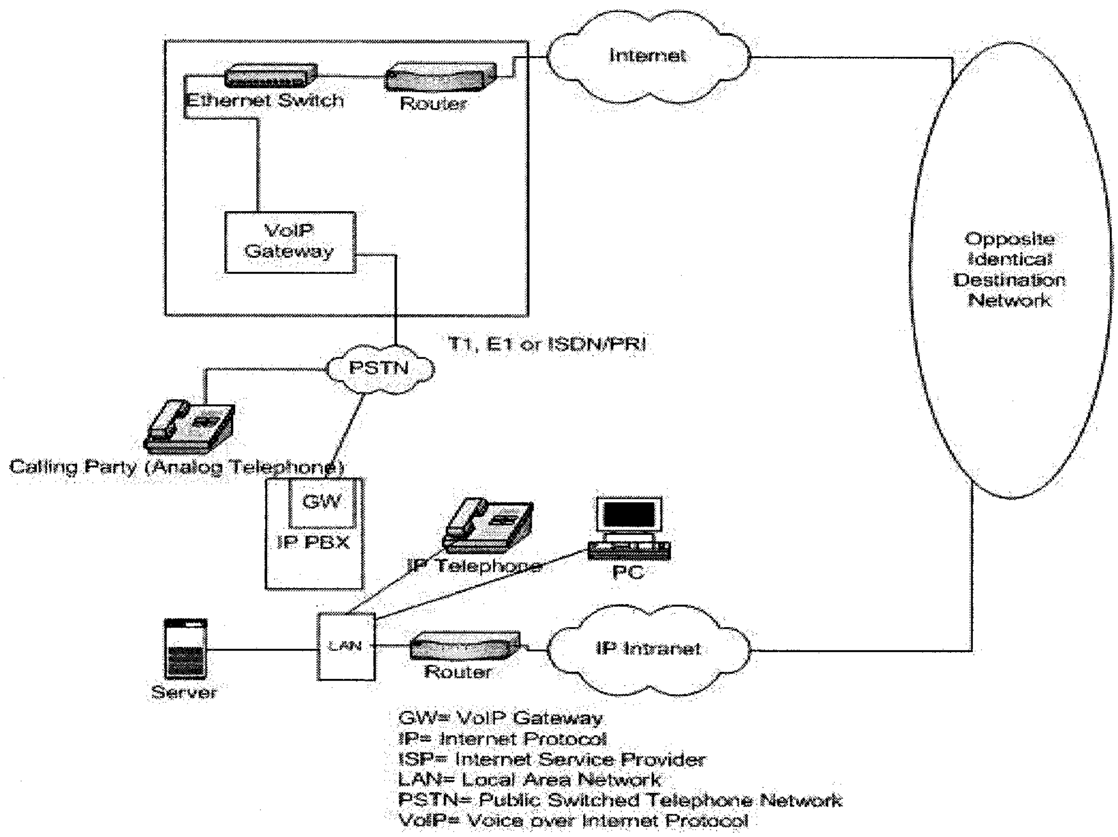

Figure 2.3 VoIP Network (Costello and Horak, 2003)

The introduction of voice over IP is considered a revolution in the telecommunications industry and has an implication on both the manufacturing and service sectors. This convergence will enable users to use packet based switching instead of using circuit based switching. As shown in figure 2.3, when a phone call is placed it goes through a voice network that connects the users to the area switch to which he belongs, then switches the call to the other switches until it reaches its destination. When the connection is established, a dedicated circuit is assigned to the call until the call ends. This is why long distance calls cost more than local calls, where the cost of the call, depends on the distance established between the transmitter and the receiver. When using the Internet however, the distance is not relevant, since the voice is transformed from an analogue to a digital signal that is transmitted onto data networks. This is done using dedicated software.

Other services also emerged such as Integrated Services Digital Network (ISDN) which simply permits users to use voice and data applications on a common digital network. Users can therefore enjoy integrated services that include voice, video, data and text transmission on the same network.

Last but not least, another rapidly evolving technology is the mobile communication. Mobile communication consists of transmitting voices or data (depending on the generation) wirelessly to users using mobile phones or mobile devices. Messages are transmitted using microwave carriers from a base station to another. Mobile switching centres (MSCs) route packets from the message source to its destination. MSCs are connected to landlines to PSTNs transmitting messages to residences as well as to Private Branch Exchanges (PBXs). (See figure 2.4)

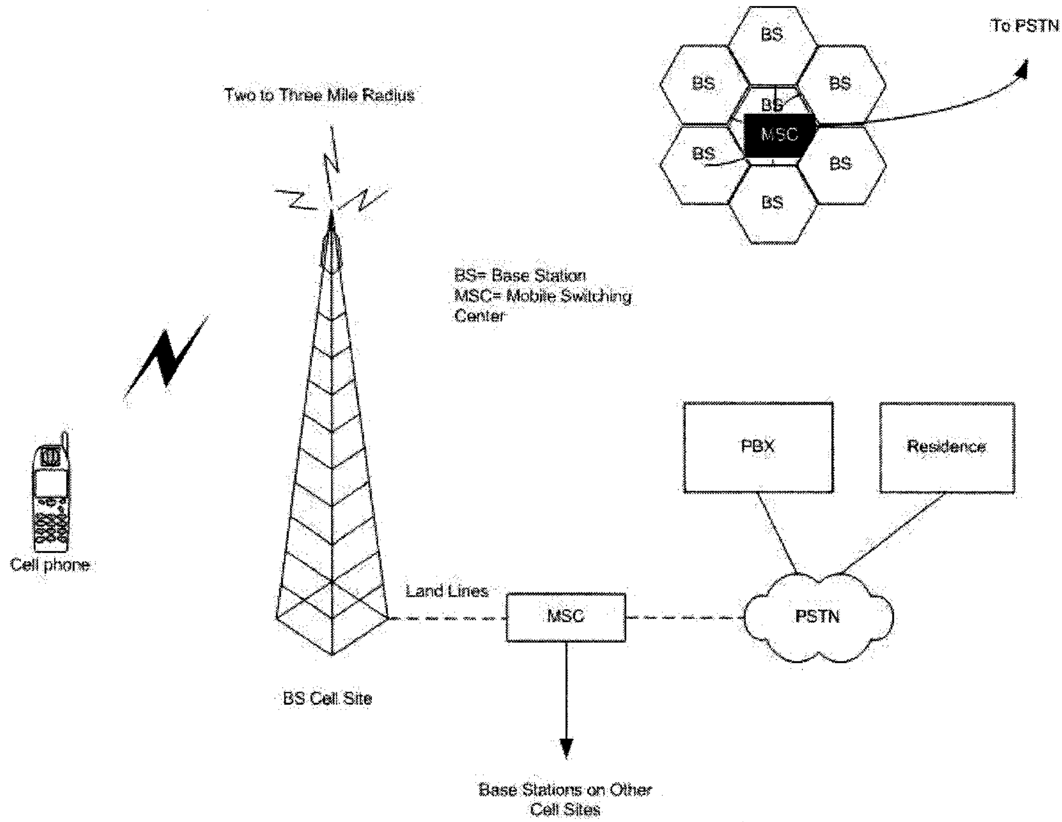

Figure 2.4 Wireless Communication Network (Costello and Horak, 2003)

Normally when the wireless device (such as a mobile phone) is switched on, it keeps identifying the network within which it is located. When a call is made, the mobile device places a call request to the MSC using the closest base station geographically. The MSC in turn calls the destination's PSTN. When the connection is established between source and destination the channel is switched to initiate communications between the two nodes. As voice or text messages can be sent locally or over distances, it can also use international networks, and in that case the roaming services are used.

It is important to know that wireless communication standards are quite different in various countries. These various systems and standards are generally incompatible. For instance, the narrowband cellular systems transmitting voice are analogue networks and are generally referred to as the first generation (1G). Second generation technologies (2G) use digital systems.

Both 1G and 2G cannot generally be used to transmit data[5]. As 1G and 2G technologies do not offer data communication, the '2.5G' emerged as a technology offering data communication. The 2.5G technologies is a middle step forward to the third generation (3G), that offers a wide variety of services coupled with increasing data transmission rates.[6]

With the increasing usage of Wide Area Networks (WANs), Local Area Networks (LANs) also developed with their own supporting protocols such as Ethernet and Token Ring. Networks emerged with different protocols; internetworking technologies became necessary to enable connecting between different networks. Products such as Bridges connect between different compatible networks (using Layer 2 in the OSI model see figure 2.1 above), while routers connected between different LANs using different path for data packets (using Layer 3 in the OSI reference model). Gateways connect networks with different natures such as data, and voice networks to support services such as Voice over IP (VoIP) services.

On the voice communication side, enterprises use the Private Branch Exchange (PBXs) that provides switching calls inside the enterprise as well outside its boundaries. Traditionally, PBXs use time division multiplexing (TDM), however technologies are

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[5] Advanced Mobile Phone Systems (AMPS) is an example of 1G systems that use cellular analogue systems (800 MHz). Digital 2G systems uses different bands: 800 MHz, 900 MHz, 1400 MHz, and 1500 MHz are used in Japan, while in the US it uses the Time Division Multiple Access (TDMA) technology uses the 800 MHz band. GSM networks widely are used in Europe uses 800 MHz, 900 MHz and 1800 MHz frequency bands.

[6] Note that with the increasing demand on data networks, several technologies were introduced such as the ISDN, B-ISDN, ATM, Frame Relay, DSL (Digital Subscriber Line), Cable Modems, SONET (Synchronous Optical Network).

converging towards using packet switching technologies in PBXs. For smaller enterprises Key Telephone Systems (KTS) are generally used when less then 40 stations are needed. Other complex systems are used to control inbound and outbound calls for heavy traffic business call centers. Such systems are called the Automatic Call Distribution (ACD).

Communication equipment comprises switches, routers, modems and PBXs, which require various network management software in order to manage telecommunication traffic. Network Management software packages assure system security, manage cost accounting, monitor network performance, detect problems that arise within networks, and correct them.

2.2.2 Telecommunication Equipment Industry Trend

In 2001, the worldwide ICT sector suffered dramatically. This industry shakeout heavily affected almost all manufacturers contributing to the ICT sector[7]. It is worth mentioning that the *telecommunication services* sector suffered less than others. This is explained by the increasing demand on wireless services by individual users. To understand the severity of the situation consider that before the Internet bubble burst, the Canadian ICT sector enjoyed profits above 5 billion dollars , these profits turned into losses in 2001, with this industry losing more than 3 billion dollars (Beckman and Fritsche, 2004). The Canadian ICT sector, however, has started witnessing an increase in profitability since year 2003.

Despite this industry shakeout, the Standard and Poor's Survey (2004) for communication equipment based on data from the US Department of Commerce, highlights the fact that there is a strong momentum in new orders for communications

[7] The ICT sector comprises computer and electronic product manufacturing, including communication equipment manufacturers telecommunication services and computer systems design as well as related services)

equipment. The report also shows positive demand signs in the wireline (non-wireless) equipment sector due to lower pricing for high-speed digital subscriber (DSL) and cable modems. In the wireless communication sector, the report indicates that operators still witness increased demand for wireless services and a particular interest for media and data wireless services.

Enterprise customers (such as large financial institutions, oil and gas companies) are pulling demand for Ethernet and fast Ethernet switches in order to offer higher bandwidths and transmission speeds. As reported by Standard and Poor's, most of the network backbones are already capable of transporting multiples of terabytes per second, the main problem however is that most of the internet users are still connected with 56Kb (kilobits) modems which puts pressure on service providers to find new innovative technologies to provide data to consumers.

IDC[8] projects that 100 million new users will access the Internet annually between 2002 and 2006; this high demand for Internet usage all over the globe exerts tremendous pressure on communication equipment to upgrade old networks and build new ones. As a consequence, the current trend in the communication industry is towards three major technologies in the communication sector: a) optical and fiber technologies and equipment; b) wireless technologies and equipment; and c) broadband equipment. Almost one third of capital spending will be directed towards investment in one of these technologies or equipment within the next few years.

As highlighted by Standard & Poor (S&P)'s, a small number of manufacturers dominate the equipment sector (see table 2.1 below), these manufacturers are part of an oligopoly. Small and midsize firms however mainly focus on offering access equipment and local telephone loop technologies.

[8] IDC is a global provider of market intelligence for the information technology and telecommunications industries.

Table 2.1 Major Communication Equipment Manufacturers (S& P, 2004)

Sectors	Communication Equipment Sector
Wireline Sector	Alcatel (France), Fujitsu Ltd and NEC Corp. (Japan), Cisco Systems Inc. and Lucent Technologies (USA), Nortel Networks (Canada) and Siemens AG (Germany)
Wireless Infrastructures	Lucent, Motorola Inc (USA), Nokia Corp. (Finland), Telefonaktiebolaget LM Ericsson (Sweden).

As Standard and Poor's note, wireless network equipment is categorized into two types of equipments: wireless handsets, and wireless equipment. The top five wireless mobile (wireless handsets) manufacturers accounting for almost 70% of the total handsets shipped are Nokia, Motorola, Samsung, Siemens, and SonyEricsson. On the wireless infrastructure side, Ericsson is currently the most important, followed by Nokia, Siemens and Nortel.

Most of the wireless infrastructure technology deploys global system for mobile communication (GSM) technology (2G and 2.5G generation); however, there is a technology shift in that field where the Wideband Code Division Multiple Access digital technology (WCDMA or 3G) is to replace the current GSM technology. Although WCDMA offers a small coverage radius compared with that of GSM, it offers 27 times the channel capacity than that of GSM systems. Due to the limited coverage of WCDMA, the estimated number of base stations has to be increased nine-fold compared to that deployed for GSM, hence forecasting a high demand for suppliers of this technology is forecasted.

The wireline equipment can be separated into 3 categories (Standard and Poor's, 2004): broadband equipment, optical equipment and data networking equipment. Broadband access equipment mainly includes DSL, cable modem, and fixed wireless. The main suppliers for these technologies are Alcatel, Motorola, Adtran Inc. and Cisco. On the digital subscriber (DSL) side, Alcatel is the world leader. Motorola leads the cable connections market followed by Toshiba, Thomson SA, and Terayon Communication Systems Inc. In the case of Cable Modem Termination Systems (CMTS), Cisco is the leader, followed by ADC Telecommunications Inc. and Motorola. Lately, Scientific Atlanta and Motorola dominate the digital set-top market, where Motorola as acquired General Instrument in order to dominate the market.

Optical transmission systems are used to transmit data for long distance using glass fiber. These networks are mainly composed of optical components, equipment, and optical switches or routers using Synchronous Optical Network (SONET) or Wavelength Division Multiplexing (WDM) as transmission protocols. Note that SONET is the American National Standard Institute (ANSI) standard for optical transmission. WDM is the technology used to multiplex several light carriers onto the same optical fiber, to carry different messages each with a different wavelength. Different colors transmitted on the fiber channel represent different wavelengths. Optical components are the hardware used to build optical networks (excluding switches). Suppliers in that market are JDS Uniphase Corp, Corning, and Lucent (which "spun off" its component division), Agere Systems as well as Alcatel and Nortel. This market as is highlighted by Standard and Poor's has suffered a downturn due to slow network building. Transport equipment is used to use modulate light in order to transmit data over the glass fiber for long distances. The leaders in that sector are Nortel Networks, Lucent Technology and Alcatel. Finally, optical switches have the role of switching high volume of optical signals from one circuit to another. Market leaders in that domain are Lucent, Ciena Corp. and Alcatel.

Data networking can be subdivided into two main streams: Ethernet switches, and routers. Ethernet switches are switches for layers 2 to 7 (data link layer to the application layer in the OSI reference model, see figure 2.1), also for wireless local area network equipment (Standard and Poor's, 2004). Leaders in that domain are: Cisco, Extreme Networks, 3 Com and Nortel. Cisco and Juniper Networks Inc. dominate the routers market providing high-end, low and midrange devices.

The main industry trend, as highlighted by Standard and Poor's, is in a "historic transition" from voice narrowband to data broadband networking. Optical technology is set to dominate the wireline traffic, and circuit switching is being converted to packet switching to transmit data. Such a shift has a tremendous economic impact on the market. This transition or technology shift to packet switching is pushed by the increasing deployment and popularity of voice over IP (VoIP) (Voice over Internet protocol) technology that enables clients to place voice calls using data networks.

As technocrats were predicting the technology convergence in the telecommunication sector, economists like Malerba (2002) also emphasized the role of this convergence towards a more 'fluid' market structure that comprises a wide spectrum of specialization and capabilities as well as different types of users each seeking different kinds of services. The current diversity is heading towards the 'process of fusion' between for example this fusion could be witnessed between the ICT products and services as well as the audio-visual technologies. These examples of fusion are due to the increasing demand on media transmission on telecommunication networks. Malerba (2002) notes that this fusion is significantly high in the telecommunication, information technologies and Internet services sectors. This fusion between sectors made the ICT to be perceived as a single common market, where products co-evolved. For example, after sophisticated routing techniques have been developed in the mid-80s to the beginning of the 90s using mainly hardware dedicated routers, alternative means of routing have been developed using software on PCs. From this we can see that after router builders such as Cisco have been concentrating their efforts on their hardware routers, other technologies emerged using software and PCs, which gave rise to network software management companies.

Firms in that sector currently face tremendous challenges to adapt in order to survive (Malerba, 2002). Due to this convergence inertia, firms have to search for new innovative technologies that lower their costs and yet generate revenues. Threats on firms' survival do not only originate from competition, but also from 'technological standards' that are supported by several widely recognized organizations (such as the IEEE) that set standards in these fields.

A new challenge firms in the telecommunication and the ICT sector are facing is the open standard (as we previously noted). Open standards are the ones that enable different technological platforms to interact together without obliging the user to be stuck with a certain technology or brand. Relatively new firms in the technology sector capitalized on open standards. Take for example Cisco that since its early start made networking equipment that could work on different networks, Sun Microsystems who promoted open standards against IBM who until recently used proprietary technologies to protect its platform from competition. Also the promotion of the Linux platform is due to the openness of its source code that enables software developers to actually see the operating system's code and modify it according to their needs. All those pressures, technological, industrial, as well as financial have made this convergence really crucial for any firm to survive, and hence grow.

2.3 Canadian Telecommunication Equipment Industry

The Honourable Marcel Masse, former Canadian Minister of Communications signalled a long time ago in the mid eighties, the importance of the Canadian Telecommunications system stating:

"The Canadian telecommunication system is, quite rightly, a source of Canadian pride internationally. It is technologically advanced, very reliable, widely accessible, and universally affordable. It meets the needs of Canadian business, the demands of our geography, and the desires of our citizens to communicate with each other from coast to coast, Atlantic to Pacific. It is an instrument of economic growth, and instrument of national unity, and an instrument of benefit to society" (Masse, 1985).

The above passage dating 20 years ago highlights briefly but still accurately the importance of the telecommunication sector for Canada's future. Canada's geographical dimension is a vital reason for the importance of the telecommunication sector in Canada. Canada is the second largest country in the world, occupying 6.7% of the world's land area. The distance from the east to the west coast is almost 5000km. This geographical dimension imposed serious challenges on both telecommunication service providers as well as telecommunication equipment manufacturers. The need for robust, reliable communication infrastructure is not only important, but also vital for Canada's prosperity and economic growth.

As an example of governmental effort to support the Canadian Internet services and products, Canarie Inc. was founded as referred to by the ITU, Canarie Inc is a non-profit organization established year 1993. The main contributors of Canarie are the research community, the Canadian Government and the industry. Canarie has its own private network (CA*net3) that is available to researchers and government laboratories involved into the development of high performance networks. The CA*net3 initiative is a backbone connecting the US, Canada, Asia and Europe. CA*net3 is an optical network using fiber technologies offering up to 40GB capacity with the aim of supporting huge traffics that holds multi-media and video conferencing content. Those installations of fiber networks are called 'Condominium Fibre Builds'. Other then Canarie, other research networks using dark fibers exist, such as BC.NET (in British Columbia), Netera (in Alberta) and RISK (in Quebec).

The Canadian ICT industry is going through a technological change. This change (as the Conference Board of Canada 2004 report highlights) is resulting from new networks that transmit voice over the Internet called VoIP. Several firms started the VoIP business such as Vonage in the US, and cable companies such as Videotron, Quebecor, Rogers, Cogeco and Shaw in Canada. The use of VoIP enables users to deal with long distance calls exactly as local calls, dialing local numbers.

These huge internet based technologies currently introduced will also have implications on the type of players in the market (as highlighted by the Conference Board of Canada), where present cable companies providing television services will be able to enter the phone market as well, and vice versa, where telephone service companies will be enabled to offer television services. This technological shift is forecasted to stimulate severe competition between different players in the ICT sector. These players include communication equipment manufacturers, telecommunication services providers, cable operators as well as other players in the ICT, such as software service companies.

Pelton (1983), when studying the development of telecommunication technology starting from telegraph in the 1800s to the wide advancement in data and voice communication, stated that there is a significant correlation between service demand and transmission capability. In other words, with the increase of bandwidth offered and capacity of communication links, services demand will advance accordingly. An example of this can be demonstrated by the following: when transmission bit rate increase exponentially from 10 bits per second to Gbits per second currently offered, this in turn affects tremendously the types of services offered by service providers. Using such capacities has enabled transmitting highly complex data, converting voice and video to data streams, that has lead to the technological convergence we are currently witnessing.

The Canadian communication equipment manufacturers, suffered a great deal after 2001. In 2000 according to the Conference Board of Canada survey, the real production in that sector increased by 53.4%. After 2001, exports of Canadian communication equipment fell by 49%. The main reason for this severe drop in that industry is the rapid increase in Internet traffic. Some technology analysts predicted that traffic on the Internet would double each year, while others expected it to double each 100 days. Based on these forecasts, firms in the communication equipment industry aimed to capitalize on such a trend. Therefore, firms in that sector went into tremendous debt in order to provide products that can sustain such forecasted traffic. Such technologies were for example fiber optics networks, that increased bandwidth and hence transmission capacity one hundred-fold (Conference Board of Canada). The estimated demand however was far beyond the realized demand, and Internet traffic did not materialize as expected. It is therefore estimated that the US had an additional unnecessary 150 billion dollars worth of communication infrastructure. Based on all these factors, sales dropped heavily, and firms began to cut costs, take for instance Nortel whose capital dropped from 400 billion dollars in 2000 to 3 billions in 2002.

2.4 Conclusion

In this chapter, the telecommunication industry was explored, from its early starts, since Marconi, Morse and Bell, and their breakthrough innovations, until the complexity of the current trends in the worldwide market. Going through the literature, we noticed that the telecommunication industry has advanced a great deal in the last century. At the beginning, the telecommunication industry was pushed by individual efforts and innovative idea, until its complexity increased exponentially, empowering greatly the role of R&D in that industry. Also some light was shed on the significant role of deregulation, and its impact on entry of rival firms competing against incumbent ones like Bell and AT&T. The current worldwide trend in telecommunication could be summarized in four technologies; wireless, broadband, fibre and Voice over IP technologies.

CHAPTER 3 - DATA COLLECTION AND INDUSTRY ANALYSIS

In light of the highlighted theories and the current technological trend, in this chapter we will try to understand the dynamics of the Canadian telecommunication manufacturers' industrial clusters. In order to understand these dynamics, we will seek to identify and locate geographically the various regions and cities that host the Canadian Telecommunication Equipment Manufacturers (CTEMs). Having identified these regions, we will further study the nature and innovative capacity of different CTEM clusters located in different Canadian cities. Cluster dynamics will be examined through firms' exit and entry rates, as well as firms' age in each specific region followed by a regional comparison.

In order to understand the dynamics of each cluster, a longitudinal database at the firm level was built. The database was built by merging various databases (as will be seen in section 3.1) to attain the highest level of accuracy. This database enabled us to study, the dynamics of each cluster, its firms' entry and exit rates, as well as its growth and how it evolved with time. After constructing the longitudinal database at the firm level, we constructed a database that described innovative output on the firm, and regional levels. This was accomplished by using data from the Canadian Intellectual Property Office (CIPO), and will be later used in Chapter 4, to perform technology analysis.

Once data was extracted and the databases built, we first started by locating firms' within cities as well as firms and cities innovative output geographically using geographical identification software. Then we used various descriptive statistical tools to understand the industry dynamics both on the city and firm level.

Section 3.1 will describe different data sources and explain the databases built, so as to present to the reader the nature of the data used in the analysis. In section 3.2, data analysis of the Canadian telecommunication equipment industry is presented. In section 3.3, we will shed some light on the major changes in the CTEM market structure and section 3.4 concludes.

3.1 Data Description

In order to address our problem, several databases were consulted. However, consulted databases often lacked one of these factors:

- Historical trends (i.e. Time Series), an example of this is Cancorp financials, where data about firms was updated regularly eliminating the previous year's figures;
- Addressing small business enterprises (SMEs), some databases only addressed large enterprises, and ignored smaller ones, an example of this is Merge Online and Financial Post Informat.Ca;
- Addressing 4 digits or higher, SIC or NAICS codes, some databases only address 2 digits SIC or NAICS, and therefore do not provide any information in a more detailed industrial level. In other words, 2-digits SIC or NAICS often address the whole manufacturing industry, which is not suitable for our analysis. An example of this is OECD firm level study provided at www.oecd.org;
- Lack of details on the city level, most of the databases installed at Statistics Canada or Industry Canada provided to us were addressing the national Canadian or provincial level.
-

In order to verify our hypothesis, building a longitudinal database from the above mentioned sources seemed mandatory.

The following databases partially solve the above mentioned problems and will be used to build our database:

1- Dun and Bradstreet Canada;

2- CanCorp Financials;

3- Canadian intellectual property Office (CIPO);

4- Canadian Business Patterns (CBP).

In the following sections we will explore each data source in details.

3.1.1 Dun and Bradstreet Canada

Several researchers (like Beaudry, 2001; Birch, 1987) have used Dun and Bradstreet to study industry concentration as well as clustering. Digital versions of D&B were not available to us; therefore, data have been scanned manually from the yearly manuals of Dun and Bradstreet Canada (years from 1998 to 2004). Data collected are mainly addressing two 4-digits SIC codes, 3661 and 3662. The 3661 SIC code addresses telephone and telegraph apparatus and the 3662 SIC code addresses radio and television transmitting signaling, detection equipment apparatus. Due to the wide spectrum of firms' activities that the 3662 SIC code includes; companies have been filtered one by one, to only retain firms in the telecommunication equipment-manufacturing sector. It is worth mentioning that D&B Canada includes only the top 20,000 firms in the Canadian Economies according to their yearly sales. Therefore small companies with limited revenues are not listed, and even removed when their sales decreases. However this downfall was compensated by merging the data from Cancorp Financials together with that of D&B.

D&B provides the following data for each company listed:

- Firm name;
- Yearly sales;
- Year of establishment;

- Yearly employment. (Employment is divided in employment here and employment total) ;
- Street address;
- Postal codes;
- City;
- Province.

The scanned database also includes the information whether this firm has only a single location (denoted by SL) or whether it is a 'headquarter' and has other branches in other locations. As explained earlier, the database includes only the top 20,000 Canadian firms by sales, therefore it cannot be used to analyze exit, since the removal of a certain firm from the database does not specify whether it is defunct nor has exited the market. However the year of establishment could be used as an indication of market, or cluster entry. It is worth mentioning that the firms presented here are firms' headquarters.

In order to determine the surviving age of firms, it was assumed that the reference date is 2004. For firms missing data for the year they were established, the year from the D&B catalogue was used instead. For each data point where some data is missing, a statistical mean between the value from the previous and next year is put, assuming a linear relation between yearly figures.

3.1.2 CanCorp Financials

Data Collected from CanCorp Financials are much wider than what D&B Canada is offering. It offers the company headquarters' name, address and location, its legal status (private or public), its status (defunct or active), the main business of the firm, the reasons of whatever changes in its legal status. For example if some firm is defunct, the reason is classified, it states whether it is due to financial crisis, or whether another firm acquired it for example. The database is being updated from year 1985, and lately from year 2003 private companies are added to the database on a regular basis. The downfall of using CanCorp Financials is that it does not offer any time series for any of the variables supplied. Even though CanCorp Financials provides a considerable amount of financial figures, they are far from complete for the majority of the variables needed for our study.

SIC codes used are 3661: for telephone and telegraph apparatus, 3663: for radio and television broadcasting and communication equipment and finally 3669: for communications equipment. The above SIC codes are 1987 SICs according to the US classification. The following concordance table shows the description of the SIC and NAICS codes used in the analysis. Please note that NAICS 1997 is similar for communication equipment for years 2001, 2002, and 2003.

Table 3.1 SIC and NAICS concordance table

NAICS 1997		US SIC 1987	
3342	Communication Equipment Manufacturing		
33421	Telephone Apparatus Manufacturing	3661	Telephone and Telegraph Apparatus
33422	Radio and Television Broadcasting and Wireless Communication Equipment Manufacturing	3663	Radio and Television Broadcasting and Communication Equipment
33429	Other Communications Equipment Manufacturing	3669	Communication Equipment

3.1.3 Merging CanCorp financials & Dun and Bradstreet

The two databases are different in nature; however merging both of them enabled us to gain a wider, consistent view of the industry dynamics. While data provided in each of the databases is non homogeneous, the merge took into consideration only common criteria between both. As a result, the two sources provided the following: firm names, patenting activities for those firms, location data like city and province, and year of establishment. Other data could not be merged, for example D&B provides employment (here and total)[9] while Cancorp financials does not provide employment data for most of the firms, and this is why we used data from 'Canadian Business Patterns' (as will be presented later) to understand growth, and employment issues.

Cancorp financials provides several financial ratios, which are not available at D&B. The merge however will enable us to use the joint table to determine entry rates in the industry, location of these firms, and the innovative performance of the major Canadian firms in the targeted industry.

Again, the use of 4-digits SIC codes included a considerable number of firms that are related to communication equipment but not to the telecommunication equipment one. The difference is that communication includes any type of communications such as radars, military equipment, and communication equipment used in tracking vehicles. it also included technologies such as GPS, alarm systems and so on. All companies had been scanned one by one, using 'business.com' and 'Hoovers Online' to insure the highest level of accuracy in filtering all firms, so as to study firms only associated with telecommunication equipment.

3.1.4 Canadian Patents Database

The international patent classification code (IPC) is used to identify patents and their relative technology, and will be used later in chapter 4. Since we are mainly addressing the communication equipment inventions the corresponding IPC code used is the H04 standing for electric communication techniques, which includes transmission, broadcast communication, multiplex communication, secret communication, transmission of digital information (e.g. telegraphic communication) and telephonic communication.

[9] 'Here' identifies employment at that particular location, and 'Total' identifies the aggregate employment within a firm across all its branches and subsidiaries.

Two main sources for patents were tested, the United States patents and trademark office (USPTO), and the Canadian intellectual property office (CIPO). In testing several general queries addressing communication equipment with Canada as the source of invention, results did yield a higher number of patents for the CIPO then the USPTO. Based on that, the source of patents used in the analysis at hand is the Canadian Patents Office. While the same results might not be true for other industries, the frequent use of the CIPO by Canadian innovators in the telecom sector, demonstrates the importance of innovation protection in that industry. Such an importance is magnified by the existence of large Canadian corporations such as Nortel which, on the one hand, patent their inventions in order to increase the barrier to entry and protect the economic value of their inventions. On the other hand, smaller firms patent in order to appropriate their innovations against such incumbent market players. Data extracted from the CIPO mainly contains the following variables: year of was issue, the patent owner , innovator's names, innovators cities and provinces, and patent description.

3.1.5 Canadian Business Patterns (CBP)

Data provided by the Canadian Business Patterns, covers years 2000 to 2004. Two formats are available using NAICS 1997-2002 or SIC-E 1980. The format used in our analysis is the NAICS 1997 with 4-digits codes (3342). The database mainly includes the number of establishments, per Canadian cities and provinces, for firms with sales greater than 30,000$ annually. Establishments are categorized into 8 groups according to employment categories. The 8 employment categories range between 1-4 employees to 500 + employees.

3.2 Firms, cities and clusters analysis

In order to understand the dynamics of the Telecommunication Equipment Manufacturers Clusters (TEMCs), our analysis will target two main areas. The first area, presented in section (3.2.1) will target the firm and city (or cluster) level analysis. The second area, presented in section (3.2.2) will target 'market structure', mainly focusing on acquisitions, mergers, and defunct firms. The next chapter will focus mainly on the technological aspect of those firms, through their business and patenting activities.

Telecommunication manufacturing activities are mainly located in 4 provinces, namely: - Ontario, Quebec, British Columbia and Alberta.

In *Ontario*, we have identified two main agglomerations Toronto and Ottawa. The Toronto region will mainly include the city of Toronto, Brampton, Markham, Mississauga, Richmond Hill and Waterloo. The Ottawa region will include, the city of Ottawa, Nepean and Kanata.

In *Quebec* we have identified one main agglomeration, Montreal. The Montreal region includes the city of Montreal, Mont Royal, Saint Laurent, and Pointe Claire.

In *British Columbia*, the main telecommunication manufacturing agglomeration is Vancouver and includes the cities of Vancouver, Victoria, Burnaby and Richmond.

And finally Alberta is represented mainly by the city of Calgary.

Three main factors will be studied here: 1- primarily employment, 2- number of firms, 3- sales for each region. The data source of employment and the number of firms used is 'Canadian Business Patterns' produced by Statistics Canada. Average sales of firms per city are presented in time series from year 2000 to 2004. The source of sales data is Dun and Bradstreet.

3.2.1 Sales

Figure 3.1 shows the evolution of sales figures sorted by each of the five main identified clusters, and Waterloo city that hosts the firm "Research in Motion" delivering state of the art wireless telecommunication equipment. We did not find a high concentration of firms around, or in Waterloo except for individual firms scattered in smaller cities like Stratford (23 miles away from waterloo), London (50 miles) and Cambridge (15 miles).

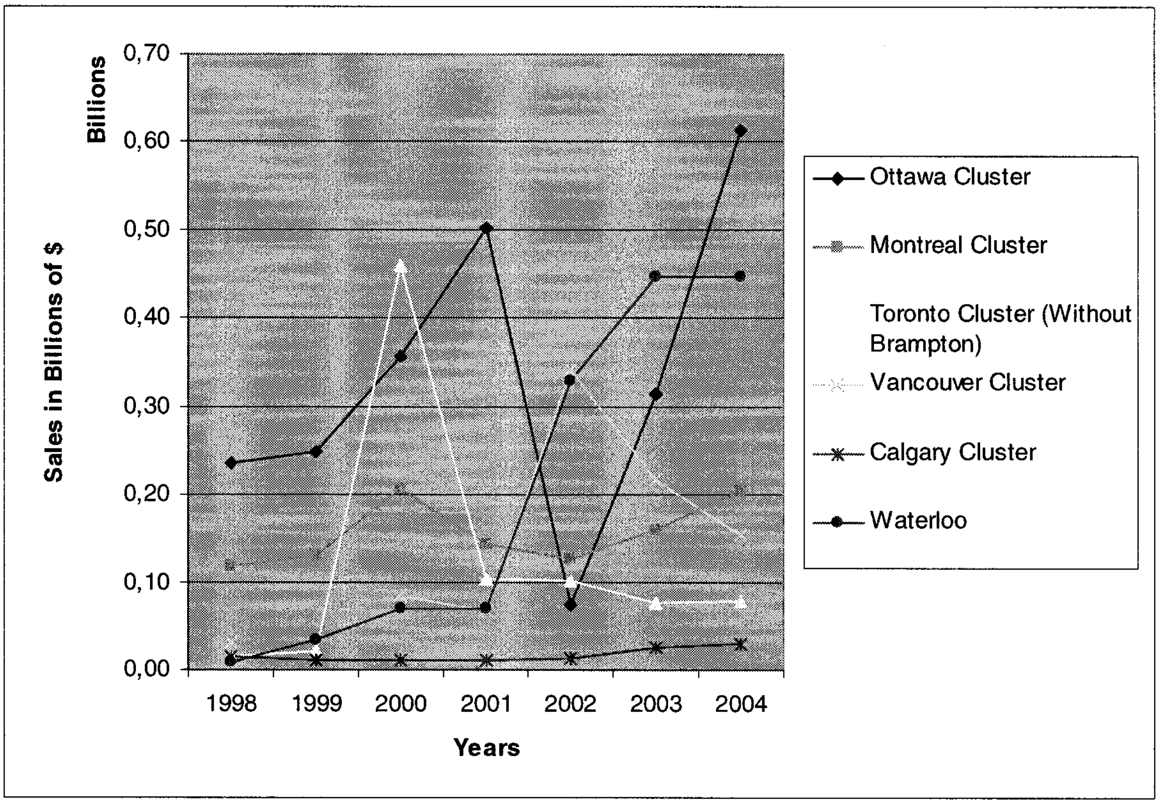


Figure 3.1 Sales per Cluster

The Toronto cluster over exceeds other clusters in terms of sales, of course this is due to the existence of Nortel and its head office in Brampton. In Brampton, Nortel holds around a thousand employees, mainly diverted between sales, finance, and other managerial jobs. Sales figures are given by firm and not by plant which explains the dominance of Brampton which includes consolidates sales of Nortel.

If we include Brampton in the comparison, other clusters sales appear infinitesimal (see figure 1 in annex). The effect of the IBBB is quite clear on Brampton (or Nortel), where sales dropped heavily from over 25 billion $ to almost 5 billions $ in 2000-2001. It is important to keep in mind that Nortel has offices/plants scattered all over Canada mainly in Ottawa, Saint-Laurent, St John, Winnipeg, Vancouver and Regina. As we will see later, Ottawa is the main office responsible for R&D, and innovative activities.

Now if we take a historical perspective, in 2000, Toronto (excluding Brampton sales), and Montreal, were the first two clusters to get affected spontaneously with the IBBB. The prime reason for this is that Toronto and Montreal, both host the major headquarters for multinational firms, delivering state of the art telecommunication equipment. And as the IBBB had an international effect, but primarily in the United States, clusters focusing mainly on sales activities were its primary victims. Figure A-3 in annex, shows the effect of the IBBB on different locations inside the Toronto cluster, that includes; Toronto city, Brampton, Markham, Mississauga and Richmond Hill.

While Toronto and Montreal witnessed a spontaneous drop in sales in 2000, that of Montreal cluster was less severe and declined gradually. In the Montreal cluster, the cities that were mainly influenced by that drop were Montreal and Saint-Laurent. While the shock had a direct influence on Montreal city, the effect was a bit delayed for Saint-Laurent. It is also clear, that Montreal city has not recovered yet from the downturns of the IBBB, while other cities, like Saint-Laurent, Pointe Claire and Mont Royal seem to be recovering slowly but surely. (see figure A-2 in annex for details).

In 2001, and while sales figures were dropping for Montreal and Toronto, Ottawa suffered its sudden collapse. The main question that poses itself is why Ottawa had a somewhat delayed shakeout. The main explanation we can provide is that, while Toronto and Montreal held the major role in selling telecommunication technologies, Ottawa had the major role (as we will see later) in producing them. As firms headquarters, located in Toronto and Montreal tried to manage the crisis, Ottawa was still not affected. But as firms had to start cutting expenses, and exercising severe layoffs Ottawa, began to shakeout consequently.

Within the Ottawa cluster (see figure A-3 in annex), Kanata seems to be the most affected by the IBBB. While Kanata sold for almost half a billion dollars before the IBBB, its sales dropped to reach that of Ottawa city, and Nepean. Another interesting phenomenon is that, while Kanata plunged in sales after the IBBB, sales seem to be accelerating heavily in Nepean. It is worth mentioning that Nepean hosts a considerable number of firms which specialize in fiber technologies, firms like JDS Uniphase and others. Ottawa city and Kanata achieved a relatively small increase in sales in 2003, to stabilize around 0.1 billions $. The Nepean region seem to be flourishing with sales figures jumping from less then 0.1 billion $ year 2002 to more than 0.4 billion $ in 2004. This could be explained by the boosting demand on higher bandwidth provided on communication channels, that induces more demand on fiber technologies

As shown in figure 3.1, the Vancouver cluster, experienced the IBBB shock with more delay than the other clusters, mainly in 2002. Once again the major sufferer from that shock is the financial center, Vancouver. Other regions did not seem to be as much affected by the IBBB (see Figure A-4 in annex). Another noticeable remark is that the Burnaby region boomed in 2002, causing the total sales to burst between 2001 and 2002, while other regions, including Vancouver city remained almost very stable, unable to recover, until later in 2004, probably this is driven by the sever competition that Vancouver is facing, versus the other two giants, Toronto and Montreal, aiming to recover as fast as possible.

In general we can say that Calgary was not affected by the IBBB (See figure 3.1 and figure A-5 in annex). The city seems to be witnessing a substantial growth in the telecommunication manufacturing market, gradually reaching a peak performance for year 2004. This is mainly explained (as will be seen later) by the rise of firms like Wi-

Lan Inc, that entered the market in the beginning of the 1990s, and is specializing, in state of the art telecommunication technologies such as manufacturing broadband wireless communications products. In the late 1990s (namely year 1999), Axia Supernet Ltd was established as an independent operator and access manager for Alberta Super Net, with the role of monitoring high-speed IP networks. It is worth mentioning that Alberta used to host an incumbent firm in the telecommunication services sector; Telus that has lately merged with BC telecom, to form Telus Communications providing wireless services.

As shown in figure 3.1, Waterloo, is witnessing a remarkable boom. The main reason driving this phenomenon is the firm ‘Research in Motion’. Research in Motion is a leading Canadian firm that mainly specializes in providing wireless, mobile terminals for end-users. A famous product of that firm is the Blackberry product, a device that enables users to receive their emails, and respond to them using the product’s wireless embedded technology.

The reader can see the effects of the IBBB on the sales of different clusters on the maps presented in figure 3.2, figure 3.3 and figure 3.4.

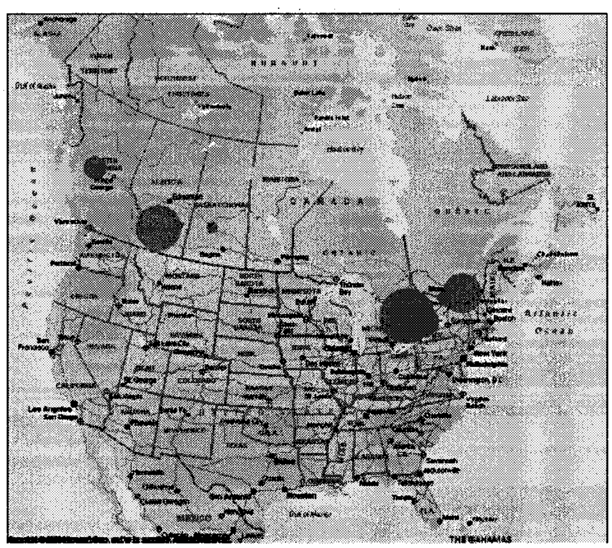


Figure 3.2 Telecommunication Equipment Sales per Cluster Map (Year 2000)

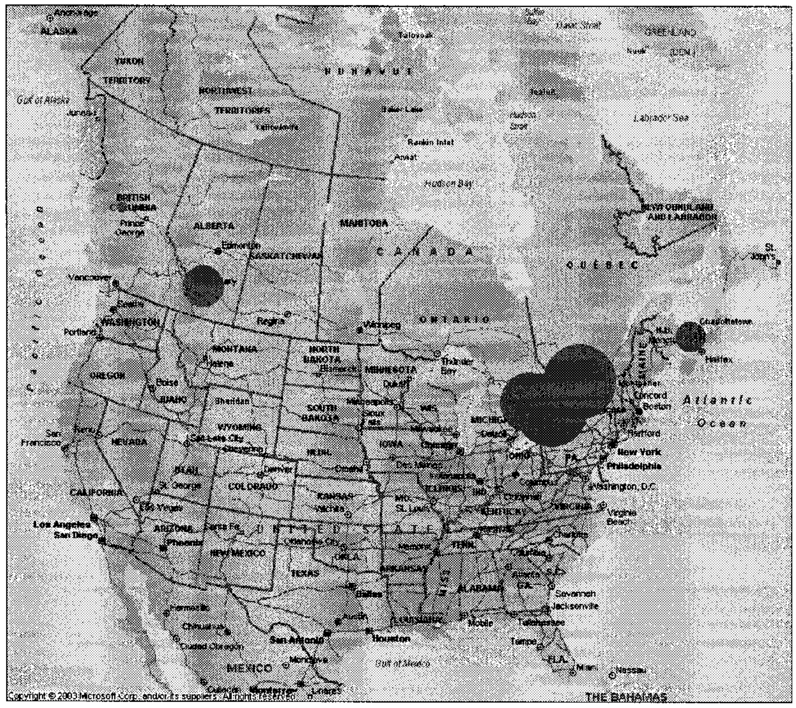
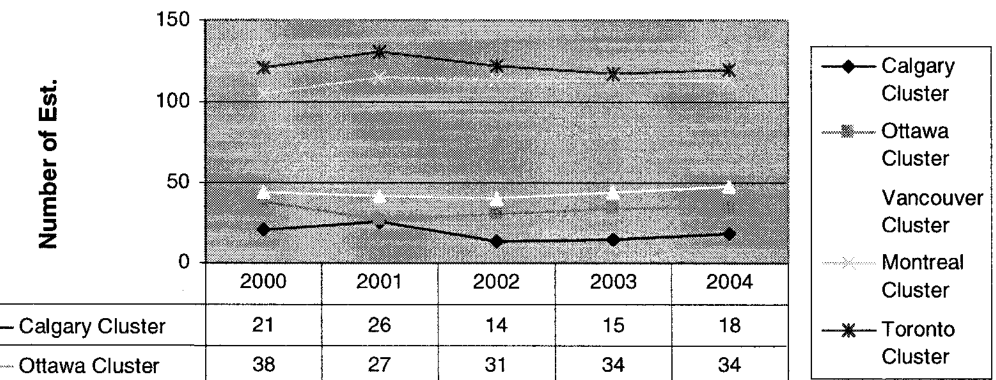


Figure 3.3 Telecommunication Equipment Sales per Cluster Map (Year 2001)

Figure 3.4 Telecommunication Equipment Sales per Cluster Map (Year 2004)

3.2.2 Total Number of Establishments

Figure 3.5 demonstrates the evolution in the total number of establishments in each identified cluster. The figure holds interesting results. The two regions that were influenced directly, in year 2000, from the IBBB are the Ottawa and Vancouver regions. For the number of firms sorted by categories in each of the identified five clusters see the figures in annex B.



	2000	2001	2002	2003	2004
Calgary Cluster	21	26	14	15	18
Ottawa Cluster	38	27	31	34	34
Vancouver Cluster	44	41	40	44	48
Montreal Cluster	105	115	114	113	113
Toronto Cluster	121	130	122	117	119

Figure 3.5 Number of Communication Equipment Establishments per cluster

The number of establishments in Ottawa dropped from 38 to 27 plants, while in Vancouver it dropped from 44 to 41 plants. Other regions, however, exhibited an increase in the number of establishments until year 2001. In 2001, Calgary lost 12 plants out of 26, Montreal was almost stable losing only one plant, and Toronto lost 8 plants out of 130 plants. This demonstrates, that the effect of the IBBB was different with respect to each region, and that the propagation of that effect with time was also different between those regions. We will see in details which sizes of establishments were responsible for the majority of losses in what follows.

Calgary

While sales figures illustrated in the previous section show that Calgary was not affected by the IBBB (See figure 3.1 and figure A-5 in annex), the total number of establishments indicates otherwise. The total number of establishments dropped from more than 25 establishments in 2001, to less then 15 establishments in 2002. That indicates that establishments that exited Calgary from 2001 to 2002, were less significant with respect to sales figures. In other words, establishments that exited did not contribute much to the overall sales of the cluster. And meanwhile firms that managed to survive the IBBB, adapted well, and performed the growth witnessed in that cluster.

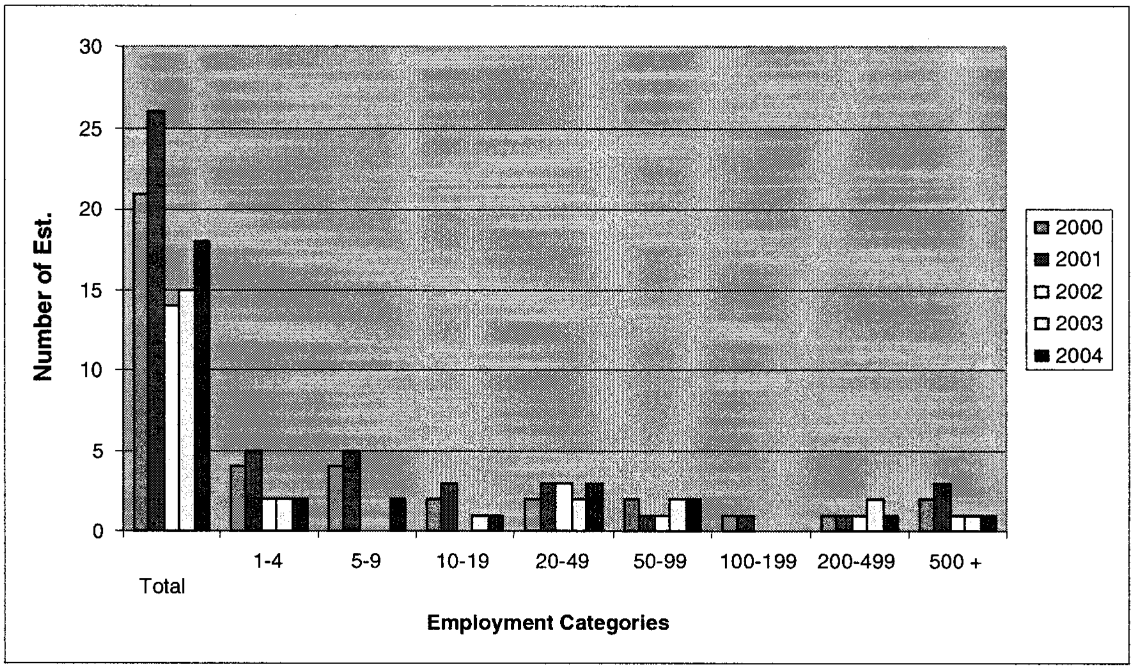


Figure 3.6 Number of Est. per Employment Category (Calgary Cluster)

Supporting our arguments, in figure 3.6, we can see that in terms of numbers that smaller firms constituted the highest number of establishments and that while the major effect of the IBBB affected almost all categories, small business enterprises (1-4, 5-9 and 10-19 Cat) were subject to a clear shrink, together with lagers establishments (500+ Cat), while medium size establishments (20-49 to 200-499 Cat) generally speaking remained intact.

We have previously referred to Wi-Lan located in Calgary; this is an example of a firm that adapted well to market demands and managed to survive, offering state of the art broadband and wireless technologies, which are the main two hot topics in terms of research in telecommunication nowadays.

If we dig deeper, we can explain this growth by an increase in the local demand due to the rise of Axia Supernet Ltd which is working with internet and other service providers to connect them to the Alberta SuperNet, which is an "ultra-high-speed" broadband IP network. The role of Alberta SuperNet is to provide broadband services to more than four hundred communities, and direct connectivity to more than four thousand municipal and governmental offices, and other facilities such as libraries, health care services facilities.

This way, Axia super net acts like the gateway of service providers receive to access Alberta SuperNet. This in turn has the benefit of delivering broadband internet connectivity to residential and business customers in rural Alberta. If we try to put those facts together, we can understand that the dynamics in the Calgary cluster could be driven by the supply chain, starting from telecommunication manufacturing facilities to serve network infrastructures like Axia and Alberta Supernet. Therefore Firms like Wi-Lan, targeting technologies such as broadband, are probably driven by local demand generated by Alberta Supertnet.

Ottawa

As Ottawa was affected in sales in 2001, its direct effect was spontaneous in 2000, with respect to the total number of establishments. This does not contradict what we said previously; in fact it absolutely supports it. While sales of bigger firms in the Ottawa cluster dropped with a delay in 2001, the shock was much more dramatic for smaller firms that contributed less to sales figures.

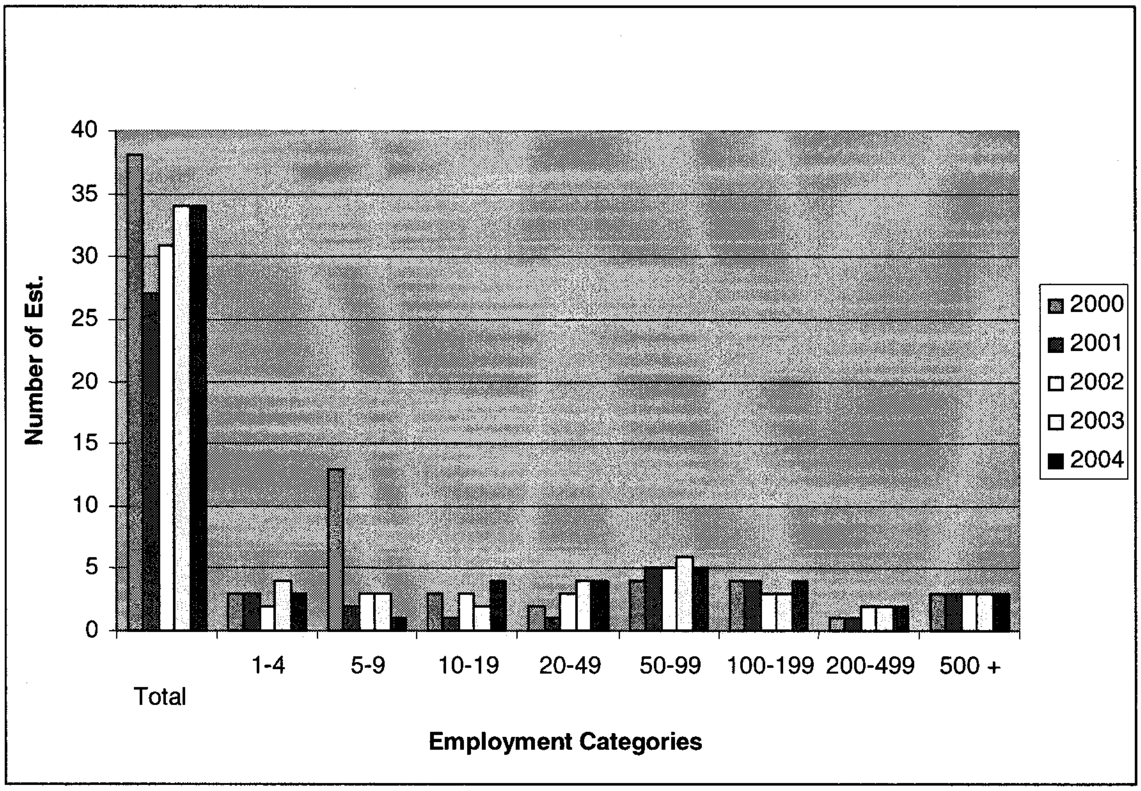


Figure 3.7 Number of Est. per Employment Category (Ottawa Cluster)

Figure 3.7 shows that the drop in the overall number of establishments was mainly due to the drop in the number of establishments in the 5 to 9 categories, mainly entrepreneurial firms driven by innovative ideas, and trying to benefit from clustering with other firms. While our numbers do not indicate whether this is an exit or a change in category, the hypothesis that smaller firms could not survive the IBBB stands to be a reasonable argument. While in general smaller establishments contributed to that drop, we can see that this drop is a compensated slightly by medium enterprises that generally speaking exhibited an increase in the number of plants, while the number of large enterprises remained almost intact. In general, we can infer that in the Ottawa cluster, larger establishments survived the shakeout, but had a severe decrease in sales, while smaller almost did not survive. However, these plants' sales revenues did not constitute much of the overall cluster sales anyways, and this is why the main resultant effect shown in sales figures was mainly representative of larger enterprises rather than smaller ones, probably trying to sell their innovative ideas to larger firms such as JDS Uniphase, and Nortel.

Vancouver

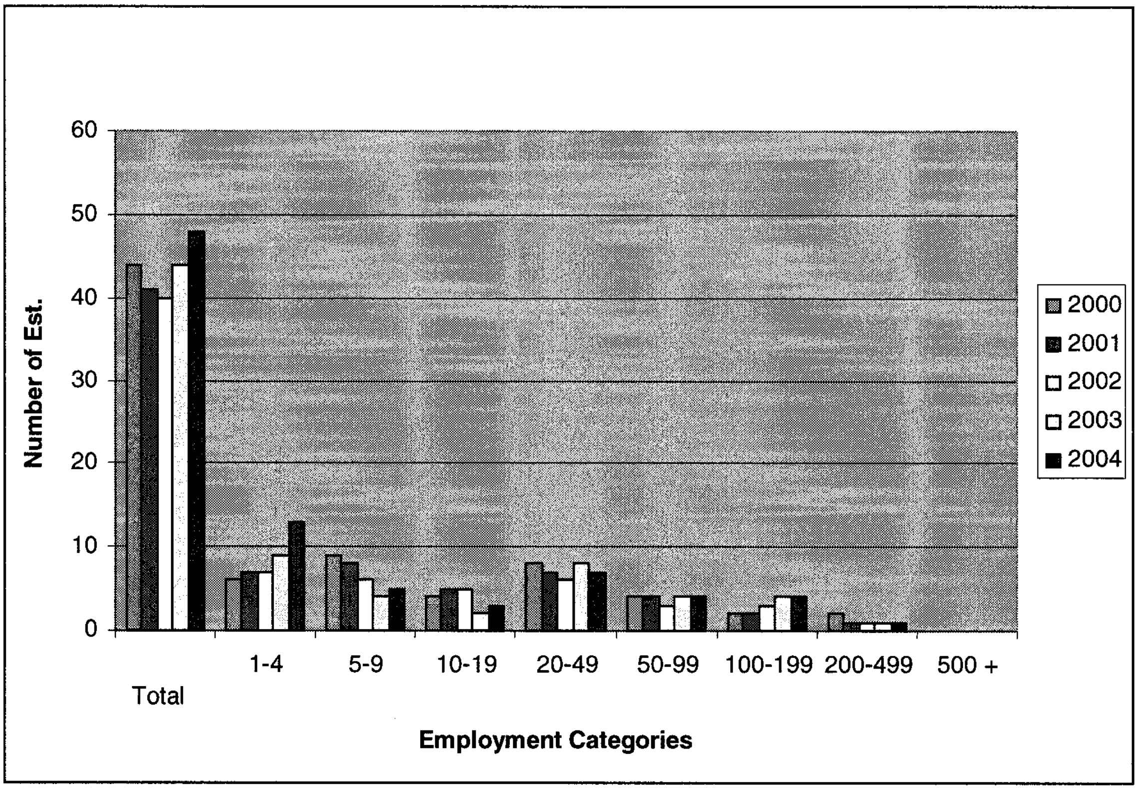


Figure 3.8 Number of Est. per Employment Category (Vancouver Cluster)

In Vancouver, we can notice an interesting phenomenon. The total number of establishments diminished until 2002, and then increased from about 40 est. in 2002 to almost 50 est. 2004. This increase in the number of establishments and the timing of that increase perfectly match the timing for the increase in the sales observed in Burnaby in the Vancouver cluster (as we have previously illustrated). If we take a look at figure 3.8, and on the 1 to 4 category in particular, we can notice that this category together with the 100 to 199 employees category are the main contributors to the increase in the total number of establishments. As for the 1 to 4 category, it currently (2004) holds the highest number of firms in the overall cluster. From this we can conclude that that small entrepreneurial establishments are starting to locate primarily in Burnaby, and that this category together with the 100 to 199 employees category are the main sources of overall cluster performance. It is also clear that the region does not hold any 500+ enterprise; it holds two categories that contribute heavily to the remarkable growth, the very small and medium sized enterprises.

From the above analysis, we can generally infer that the Vancouver cluster primarily depends on small and medium size establishments. Those firms generally speaking, do not have the sales momentum yet that their counterparts enjoy in Toronto, Montreal or Ottawa. Also this correlates quite well with the fact that the Vancouver Region as we will see later, is a relatively newer cluster that is still emerging with respect to high technologies, this is why large enterprises do not exist, while small and medium sized enterprises are witnessing growth.

Montreal

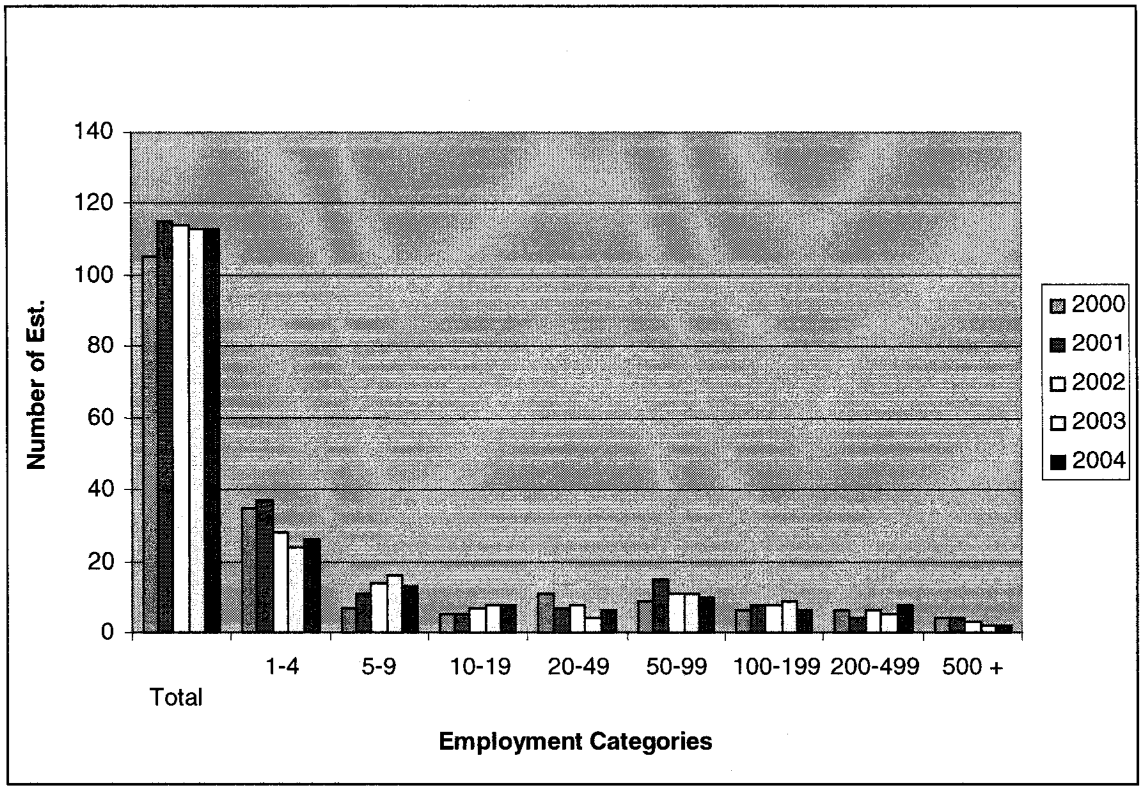


Figure 3.9 Number of Est. per Employment Category (Montreal Cluster)

The increase from 2000 to 2001 in the number of establishments is almost subdivided between all categories, with the exception of the 20 to 49, and 200 to 499 employee categories, that witnessed a decline, and the 500+ together with the 10 to 19 category that were stable. In general, as we showed earlier, sales declined in 2000, however not as sharp as in the Toronto cluster. The same happened in Montreal, with a slight diminution in the number of establishments (see figure 3.9). Still the higher level of contribution to the overall number of establishments is that of the 1 to 4 category. From this we can se that while some establishments might have moved to the 5 to 9 category others could have exited the cluster.

Toronto

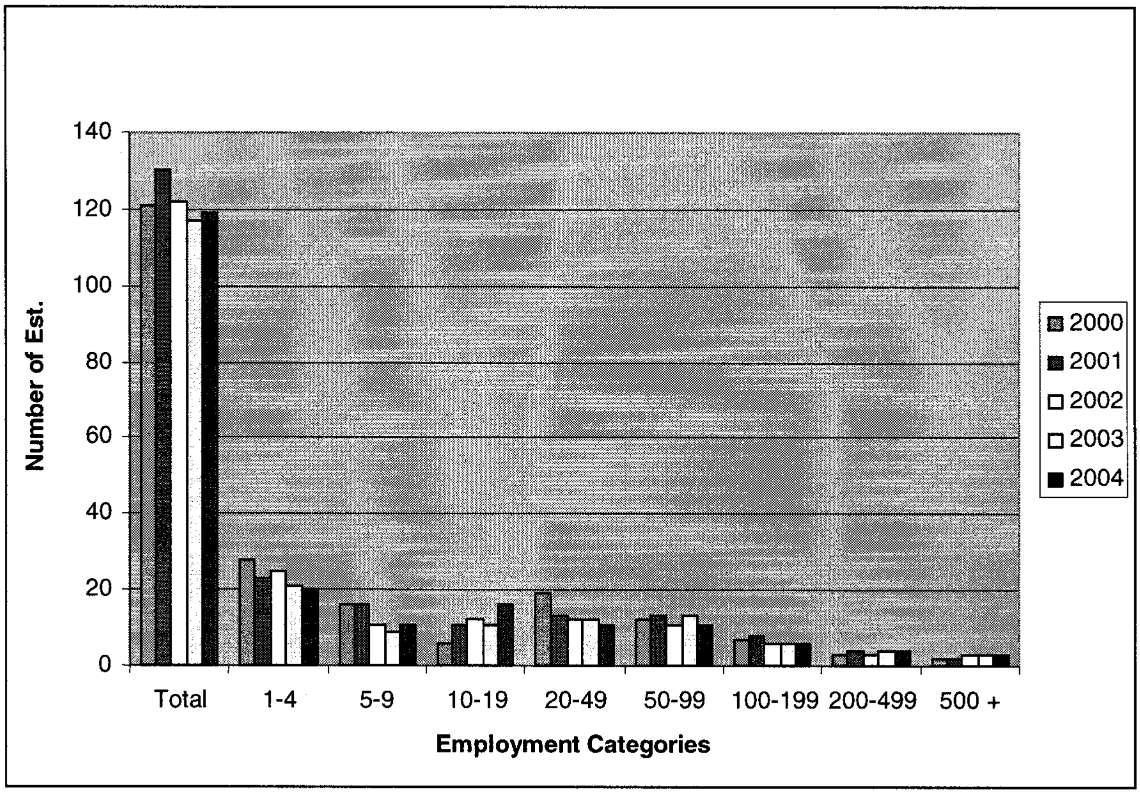


Figure 3.10 Number of Est. per Employment Category (Toronto Cluster)

Toronto cluster yields the highest number of establishments in comparison to the other 4 clusters. Figure 3.10 shows that, in general, the main categories affecting the slight decrease in the number of establishments observed from 2001 to 2003 are mainly small and medium business enterprises. The number of bigger establishments generally remained unchanged. While the 1 to 4 employee category still occupies the larger base, Toronto seems to hold a homogeneous portfolio of different sizes, in terms of employment categories. It is like a pyramid, while the larger number of firms exist at the bottom, the number decreases as employment categories of firms increase. This is due to the fact that the Toronto cluster is quite mature holding the overall spectrum of firms within its boundaries. The total decrease in the number of establishments from 2001, is generally distributed equally between establishments in different categories, which means, that even within each category, the industrial structure is quite competitive and coherent, i.e. an increase in industry profits or losses is almost shared by all categories. This in turn can lead us to a rather interesting result, while big firms have the capacity to exploit larger international markets, small and medium sized establishments, are mainly focusing to serve larger sized plants. This supply chain paradigm could explain quite well the effect of the IBBB on the CTEM cluster in Toronto. While bigger firms suffered from a direct cut in sales in 2001, subsequently to 2001, the total number of establishments began to decrease. Smaller establishments trying to service bigger ones, diminished consequently, and the whole supply chain reduced its sized equally among all categories.

3.3 Market Structure

In this section, we will take a closer look at the CTEMs through out Canada. The main source of data in that section is CanCorp Financials. Forty-six firms out of 123 firms were defunct, merged or acquired. The series of changes in the market structure in the CTEMs' market started near in the late 1980s, and the latest changes monitored in our database, is in year 2004.

Acquisitions

The first main acquisition monitored was in 1991, where RACAL Ltd was acquired by EADS which mainly specializes in the switching business. In year 2000, CANTEL Inc, located in Saint-Laurent was acquired by Rogers Communications. Another famous acquisition in the CTEMs' market is Newbridge located in Kanata that was acquired by Alcatel located in Ottawa cluster.

Mergers

The main merger that we have spotted in our database was that of JDS Fitel in year 2001 that merged with Uniphase to form JDS Uniphase mainly a specialist in fiber technologies. It is important to mention that the above described dynamics all occurred in Ottawa.

Defunct firms

In figure 3.12, we can identify that, in the TEM's market, the number of defunct firms reached a peak twice, one in the early 1990, and the other in 2000. The exit rate dropped to reach its lowest level in the mid 1990s, a very dynamics period in the telecommunication industry, whether on the manufacturing or services sides. In year 2000, defunct/exit rate reached a historical peak, of 9 firms in 2000 and 8 firms in 2001 ceased operations. The effect of the IBBB is of course clear in the year 2000 period, where the exit rate reached its peak, and entry rate was dropping severely.

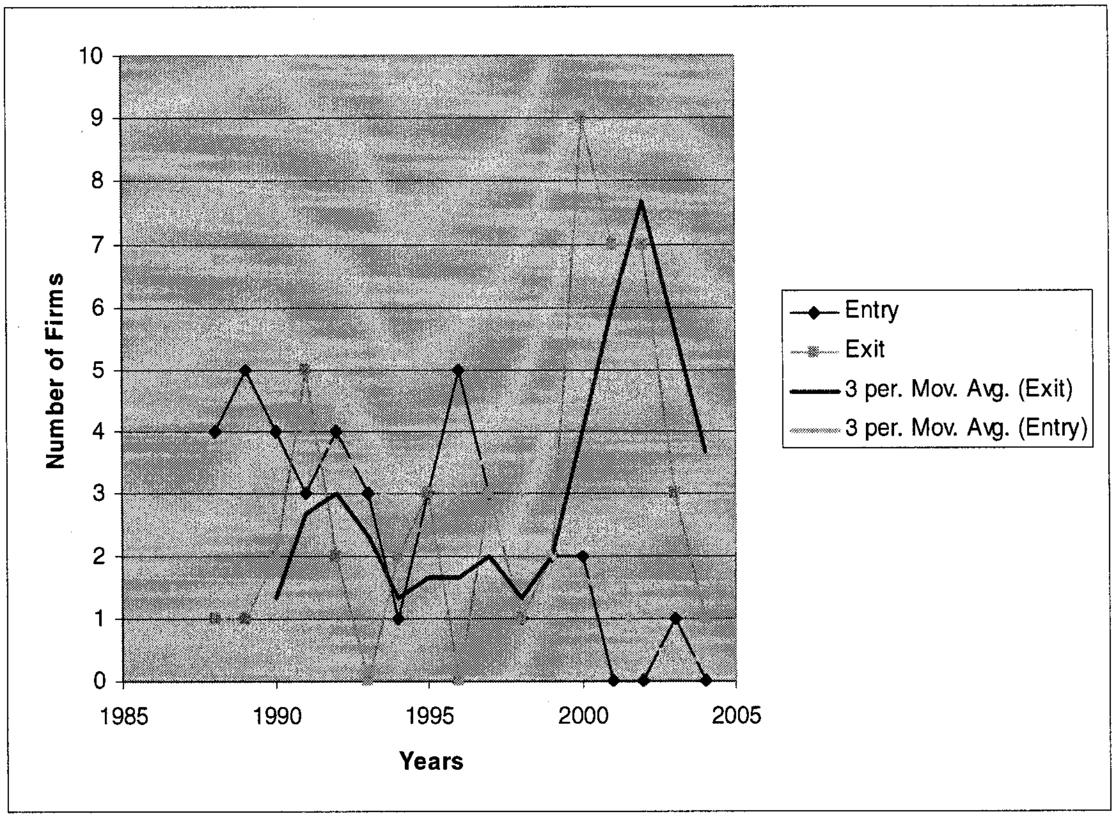


Figure 3.11 Entry and Exit of TEM firms on the Canadian Level

The average age of firms when they ceased operation was 15 years, 5 years less than the average firm in the industry (which is almost 20 years). Figure 3.13 shows that the relatively new telecom cluster located in Vancouver, is associated with the lowest number of defunct firms. Those defunct firms are mainly older ones unable to adapt to newer market demands. Followed by Montreal that, in general, seems to be a cluster less dynamic then that of Toronto and Ottawa.

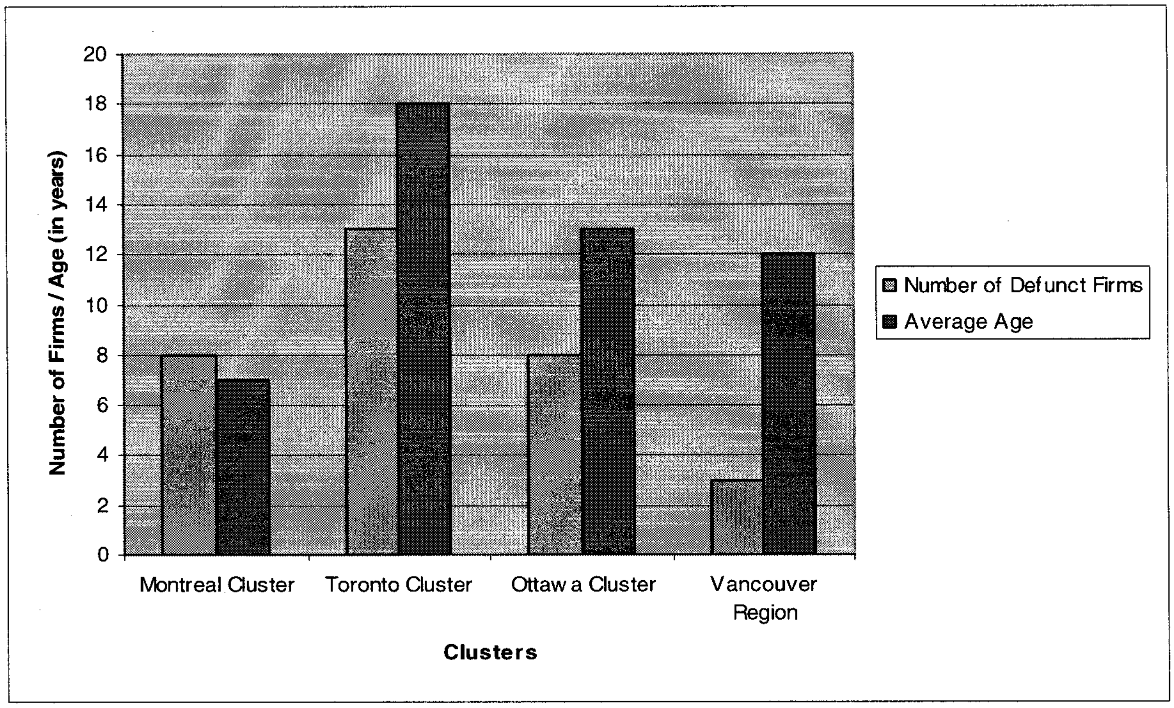


Figure 3.12 Defunct TEM Firms (by Cluster)

In Montreal, smaller firms seem to be the ones that exit the markets compared to Toronto, and equal to that of Ottawa. This is probably due to the competition ignited by incumbent firms that leads the cluster to repel new firms, with the exception of highly innovative ones. The higher number of defunct firms we based in Toronto, with a relatively higher average age then the rest of the 3 other clusters. Of course this is proportional, since Toronto in the same time, holds the highest number of firms in comparisons with others. Ottawa is similar to Montreal in the number of firms that defunct, however, the average age of firms that defunct in Ottawa is higher than that of Montreal, demonstrating that while both clusters repelled the same amount of firms from 1985, Ottawa cluster as a new dynamic cluster repelled older firms unable to offer new innovative technologies and Montreal, that could be identified as an older cluster protected older firms and did not encourage newer firms to penetrate its cluster easily.

Some of these results are quite consistent with Swann's (2001) main finding with respect to cluster birth, survival, and death. Older clusters become less attractive, and with time old firms located in old industrial clusters exit the market. At the same time, newer firms rush into new clusters such as Ottawa (Nepean, Kanata), Toronto (Mississauga...) to benefit from clustering advantages. Severe competition forced them to exit the clusters they were trying to penetrate. Lately and subsequent to the IBBB, the numbers of firms that exit the CTEM industry were at their peak at Ottawa, Toronto, Montreal and Vancouver, demonstrating that only the strongest firms into those active clusters survived the downturn of the IBBB, while smaller, weaker ones vanished.

3.4 Conclusion

The effect of the IBBB was quite visible from our analysis in this chapter. The Toronto cluster suffered the most from the downturn which was of course driven by the rapid deterioration of Nortel stocks and the apparent collapse of the industry. While Brampton specifically suffered huge losses, we remarked a recent increase in sales in the Waterloo region, driven by the firm 'Research in Motion' that manufactures wireless technologies for end users. Sales did not only drop in the Toronto region, they also dropped in Vancouver, Montreal and Ottawa.

While bigger financial cities, such as Toronto, Montreal and Vancouver were directly affected by the industry shakeout, a delayed response took place in Ottawa. While most of the telecommunication manufacturing firms, had headquarters in Toronto, Montreal, and Vancouver, Ottawa seems to be the place for smaller, innovative firms. Indeed Nortel has its main R&D office in Ottawa. And while the telecommunication industry is a multinational industry in nature, and that its demand goes beyond local demand to cover international markets, firms headquarters located in Canadian financial cities where the ones primarily and spontaneously affected. Firms located in Ottawa began to suffer. In general, Ottawa, together with Saint Laurent and Burnaby, as the sources of

R&D activities that supply innovative ideas to their headquarters suffered losses after the production side of the industry. And since the crisis came from the international, sustained by the local demand side, firms in Ottawa were affected in a some what delayed manner.

Also we have witnessed severe changes in plants' sizes subsequent to the IBBB shock. This was evident in all clusters. However, we have generally inferred that the Montreal and Toronto clusters generally held a homogenous diversification in terms of firms sizes, and that the crisis, affected almost each and every category. This was not true in Ottawa, where the main reduction in plant sizes was concentrated in the 5 to 9 employees category. Generally, smaller firms are the ones that mainly suffered from the downturn of the IBBB, with a different magnitude among different clusters, with less harm done to the largest firms. When we studied the overall sample from Cancorp financials however, we discovered that in general older firms were usually the ones exiting the market, and this could be explained by the following: While on the one hand the telecom industry started to mature, older firms unable to adapt died, while new firms had the competitive advantage to survive, on the other hand, when submitted to the industry shakeout, newer firms died, while older ones survived. We can thus draw an interesting conclusion: with a technology shift innovative ideas could guarantee firms growth, while maintaining an adequate financial structure, in the case of an industry shakeout however, firms with the more financial capabilities survive, while more innovative firms could be subject to a greater probability of death in their own clusters.

CHAPTER 4 - TECHNOLOGY ANALYSIS

In this chapter we will investigate whether there is an identified technology shift both on the innovation side and business activity sides of the firms in our sample. An interesting question to ask is: if there is any relation between geographical location and technology, and whether that shift affects agglomerations or not.

Firms' activities were collected manually from the various sites on the Internet to establish each firm's main business. Patent description with respect to time, could be an indication of whether there is a structural shift due to firm innovative capacity and change in technology. In Chapter 2 we have identified three major technologies in the telecommunication industry, mainly broadband, wireless, and Voice over IP. In the coming section we will try to understand if there is any link between the various technologies and geography and how did they evolve with time. Further we will try to infer whether there is any technological shift or trend that emerges from these patents related to cities.

In order to spot different technologies in our database, to monitor any possible trends or shifts, we have identified several keywords. These keywords were used to search through both our patent and firm databases. The identified keywords are: optics, voice, video, satellite, management, wireless, microwave, base stations, broadband, and antenna. 'Optics' is used to search for fiber technologies. 'Management' is used to search for network management software. 'Voice' is used to search for voice as well as voice over IP technologies. The keywords: wireless, microwave, base stations, and antenna are used to search for wireless technologies, and finally broadband is used to detect broadband technologies.

The innovative capacity of a particular location is derived from the location of inventors in that sector. It is worth noting that if 3 innovators invented 1 patent, while each is in a different city, this is counted as 3 separate patents. This way we can analyze the bi-directional relation between innovation output (measured using patents) and location.

4.1 Firms Activities

4.1.1 Fiber Technology

In our firm database, 32 firms, out of 295 firms, specialize in fiber optics (more than 10% of the studied sample for firms).

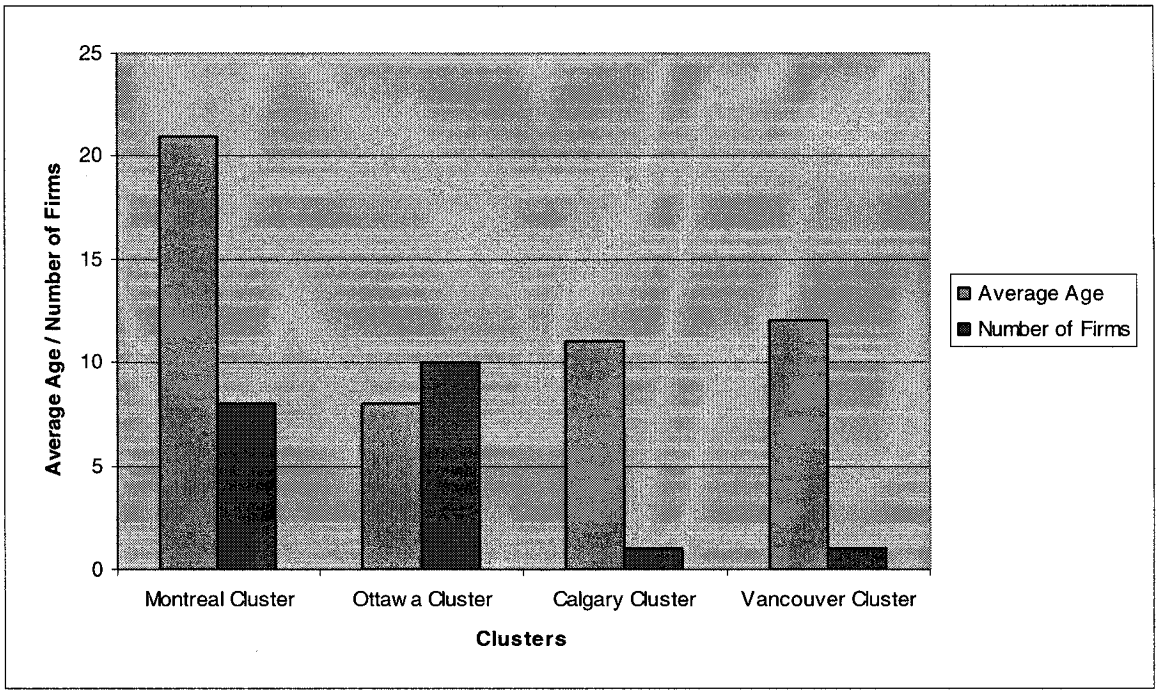


Figure 4.1 Fibre Technology Clusters

Figure 4.1 shows that the majority of the firms are divided between Quebec and Ontario. In Quebec, the main cluster specializing in fiber technology is Montreal, including the cities of Montreal, Pointe Claire and Saint-Laurent. The average age of firms that produce fiber all over Canada is 17 years. In Ontario, the firms are concentrated in and around the Ottawa cluster, mainly in Kanata and Nepean. The average age in this region is almost 10 years. Firms in Ottawa and Kanata that produce fiber technology are of average age of 5 years, relatively much less then Nepean that holds an average of 14 years. In Quebec, average firms age that produce fiber technologies is almost 14 years, compared to 10 years in the Ottawa region. Montreal city center holds an average of almost 10 years, Saint Laurent 15 years, and Pointe Claire of almost 29 years.

From the above description and figure 4.1, we can understand that Montreal is the oldest cluster that currently produces fiber technologies, and that the Ottawa cluster although relatively younger is more concentrated and holds a higher number of firms. In the meantime, Vancouver, and Calgary Cluster, both hold almost one old firm producing fiber. While Montreal is the eldest among clusters, Montreal is the only cluster able to keep up with the Ottawa. However, as we will see later, Ottawa appears to be more concentrated, and is definitely much more innovative when it comes to fiber technologies.

Now let us take a closer look at the technologies provided in some of the main clusters. We noticed a significant trend in technology that is bounded specifically to cities and regions. An example of this is the region of Ottawa. In Ottawa city, two main firms focusing on fiber technologies were identified: Solinet Systems and Innovance Inc. Both of these companies work almost on the same technologies, optical networks (i.e. routing, switching, etc.). It is interesting to know that both of these firms were established in 2000, and both specialize in almost the same technology. Solinet Systems is a startup from engineers of Nortel Networks. Solinet Systems is a good example of how a spin-off firm starts up. As we noted earlier, Nortel has its main R&D office in Ottawa, and this definitely, together with other bigger firms like JDS Uniphase, Alcatel and others, played a crucial role in providing a silicon valley[10] type of environment, enabling entrepreneurs to startup a new firm with their more innovative ideas, making their cluster of residence more innovative and strong.

[10] Ottawa Cluster is often referred to as "Silicon Valley North"

In Nepean the fiber technology started with Fitel, established in 1981, followed by Emcon Emanation Control Ltd, in 1985 specializing in fiber Ethernet switches. In 1993, Oprel technologies, which specialize in optical amplifiers, entered the Nepean Cluster. The latest entrant in that cluster was JDS Uniphase a specialist in fiber optics communication. Subsequent to its entry, JDS Uniphase merged with Fitel, and acquired Oprel technologies to form JDS Uniphase Canada in 1999, hence increasing concentration in this particular cluster. This story of acquisition is quite interesting, in the Ottawa cluster, market structure and concentration shaped up, not only by encouraging smaller firms to grow, but also, larger companies using mergers and acquisitions in order to acquire newer technologies and hence diversify their product portfolio, or to eliminate competition. This phenomenon is quite usual in the telecommunication manufacturing industry. As we previously explained in Chapter 2, giant firms, like Cisco and Nortel used mergers and acquisitions mainly to acquire newer technologies, or to eliminate newer technologies, that compete with theirs, in order to guarantee leadership.

In Kanata, the three identified firms producing fiber technologies are Tropic networks, Ceyba Corp and Meriton Networks Canada Inc. The three firms mainly specialized in optical layer network management and building optical networks. The three firms were also established in 2000.

In Quebec, the Montreal cluster hosts Positron Fiber Systems Corporation and Siecor Corp, two firms specialize in optical and broadband access systems, as well as fiber cabling (Siecor). These two firms entered the market 1994-95. Pointe Claire hosts MPB Technologies that specializes in optical communication equipments. Saint-Laurent hosts Stocker Yale Canada that manufactures optical components for optical networks. In general, entry in Saint Laurent and Pointe Claire attracted fiber optics firms mainly in the mid seventies.

Figure 4.2 spots firms producing fiber throughout Canada. Bubbles size is arranged according to the number of firms in a certain cluster.

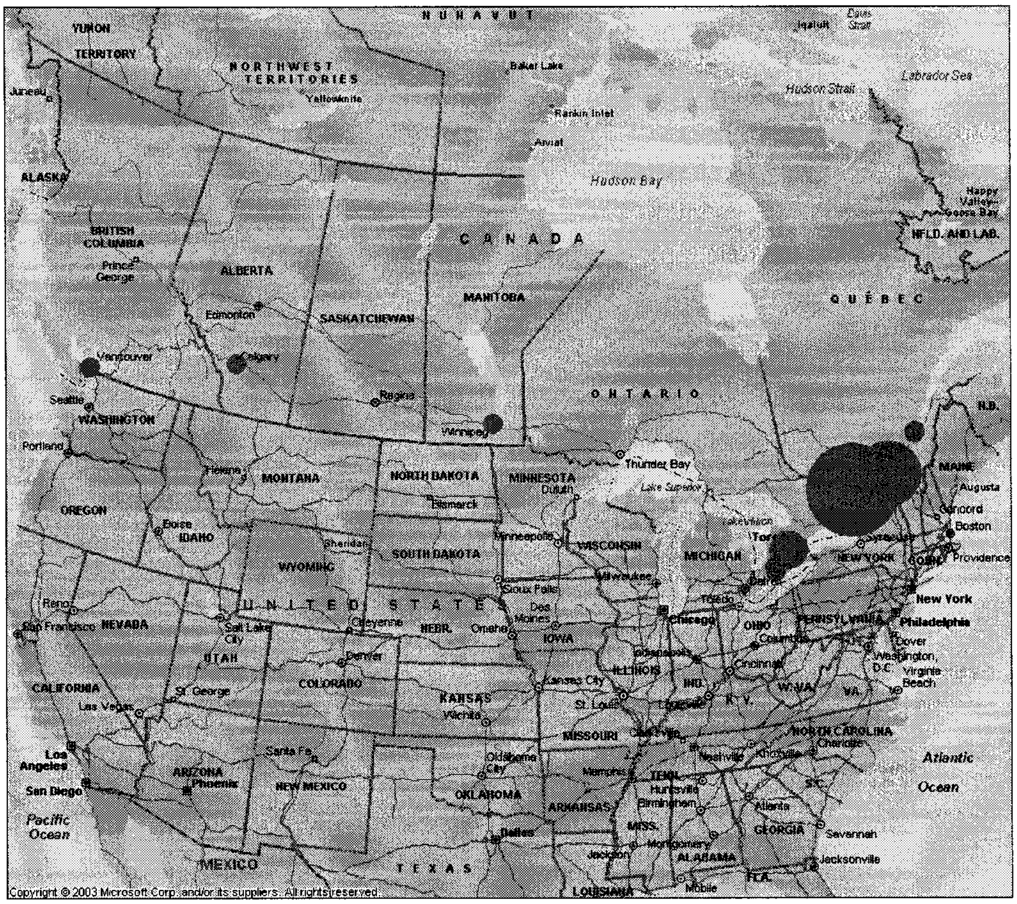


Figure 4.2 Number of CTEM Firms Producing Fibre Per cluster map

4.1.2 Broadband Services Technologies

In this section, when referring to broadband, we imply broadband equipment from the service side, not on the transmission side. In other words, we refer to the technologies enabling these services to be functional rather than the technology itself. As an example fiber technology offers higher broadband then copper or other medium used for transmission, but it is not called broadband. DSL, ADSL, and ISDN are considered broadband services. It is also important to note that broadband, is a relative meaning that refers to higher bandwidth or higher bit rate, and is relative to other bands used for transmission. For example, broadband technologies can be referred to, when talking about television stations, compared to bands used to transmit radio signals. It is important to understand, that broadband term extends from offering higher bandwidth or bit rate as compared to lower ones, to offering these technologies from the high end to the lower ends. In other words, high ends refers to equipment acquired by operators to provide services, and low ends refers to modems used by end users to access technologies such as DSL and ADSL modems.

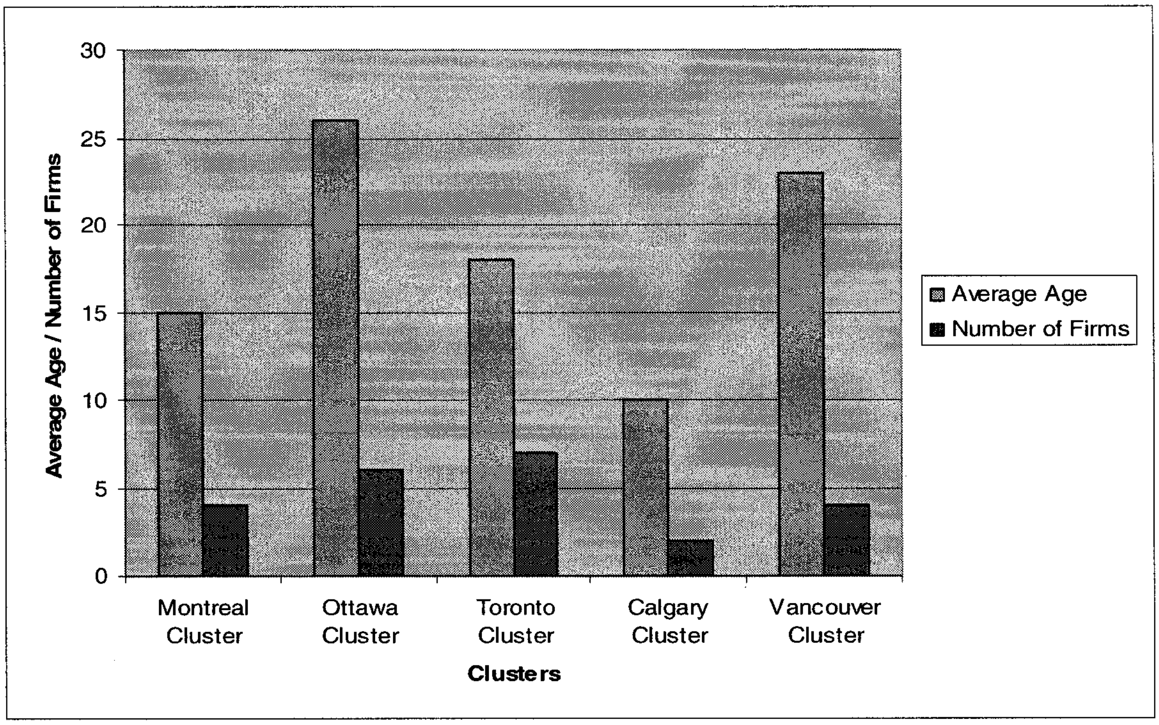


Figure 4.3 Broadband Technology Clusters

The average age for firms that produce broadband all over Canada is 21 years. Whilst on the fiber side only Ottawa and Montreal are the main producers, on the broadband technology side we can see in Figure 4.3 that Toronto, Vancouver, Ottawa, Montreal and Calgary firms are specialists. Of course we can notice two things, first that the number of firms attacking this segment is quite diversified among all clusters. This is probably due to the widespread use of broadband services such as DSL and others. These kinds of firms therefore are mainly driven by a demand pull from residence and business clients. Second, the average age of firms is quite high, in this particular technology which means that broadband manufacturing firms were probably interested in other types of communication technologies and they started to diversify their product portfolio following end users' demand aiming at higher bandwidth.

It is important to note that while broadband technologies are generally offered on wireline medium, a current technological trend is to provide these services thruogh wireless medium. Ericsson is currently focusing on wireless communication and is already investing considerable amounts in R&D for this particular area. Ericsson is mainly pursuing this research in their Montreal office.

Microtel established in 1979, is responsible of the high average age of firms in the region of Burnaby (Vancouver). Microtel is a manufacturer of broadband technologies, routers, voice over IP, and ISDN technologies. In the early eighties (namely 1981-1982) NORSAT International entered the cluster to specialize in the manufacturing and design of electronic products that are used to receive broadcast audio, video and data communication from satellites.

Since the beginning of the 1990s, Wi-Lan Inc has been located in the Calgary cluster. the firm that specializes mainly in broadband wireless communications products and technologies. In 1999, Axia Supernet Ltd was established as an independent operator and access manager for Alberta Super Net, with the role of monitoring high-speed IP networks. Again this demonstrates that parts of the commercialized technologies in that sector are mainly based on a demand pull strategy from end users in need of higher bandwidth or bit rate.

Apart from Alcatel-Kanata established there since 1986, in the late 1980s, the region of Kanata has attracted two other major firms that provide broadband technologies, mainly

Newbridge Networks (later acquired by Alcatel) and Catena Network Canada. Newbridge also established in 1986, was a worldwide pioneer in the manufacturing of broadband switching and routing technologies, from the high end side.

Newbridge however, failed to adapt to demands in the market place, and was acquired by Alcatel which benefited heavily from the Newbridge broadband line of product. Catena Network Canada produced broadband access systems that targeted telecommunications carriers, and helped them provide different broadband services such as DSL, as well as integrating voice and data access networks. International Datacasting Corporation was established in 1958 in Ottawa, and manufactured hardware and software products for data broadcasting. After a while, in 1984 this firm diverted its business to primarily focus on the production of wireless and broadband satellite equipment.

The Toronto cluster includes several important manufacturers of broadband technologies: Nortel that moved to Brampton in 1977, Ericsson in Mississauga (established in 1982), and Waverider Communications established in Toronto year 1987. Waverider Communications Inc. mainly produced Internet protocol-based bridges and routers that help manage point-to-point and point-to-multipoint broadband between service providers and subscribers.

The Montreal cluster, specifically firms in Saint-Laurent, also contributed heavily to the broadband technologies. The first entrant, according to our database, was SR Telecom, a pioneer in the manufacturing of broadband access technologies, targeting network solutions for voice and Internet operators as well as service providers. Muxlab Inc. started its operation in the late 1980s to provide video connectivity products that allow traditional coaxial cable to be replaced by copper twisted pair. Coaxial cables are used by major cable television providers to provide television services to its clientele. Firms such as Muxlab, enable transforming these cable networks to copper twisted pair ones, used for telephone cabling. Of course, such a transformation became very beneficial, especially with the exploitation of broadband services technologies such as the DSL and the ADSL that offers almost the same quality with lower costs using copper twisted pair networks. In the mid 1990s, Positron Fiber Systems entered the Montreal region, mainly aiming at providing optical and broadband access systems. And the most recent firm to enter was Polarsat Inc that provides broadband access equipments. Note that, broadband access equipments refer to devices that enable the end user to gain access to the network. For instance, the modem used to access the Videotron network is a type of access equipment.

In Manitoba, Winnipeg was able to facilitate entry for two main firms specializing in broadband equipment. Entry of both of these firms was in the mid 1990s. The first, is Broadband Network Inc, established in 1994, which builds and deploys fixed broadband wireless networks[11]. Second, Norva Technologies established in 1997 that currently manufactures broadband receivers, transceivers, and gateways for satellite.

From the above we can confirm that firms located in the different five clusters, identified this current need for broadband services, and started to diversify their production and R&D activities. In the different clusters, these firms were relatively old and capable of investing in such technologies especially on the high end line of products provided to operators. We have also seen that firms, like Ericsson, started to identify the need of offering broadband services using wireless technologies such as the CDMA technology or what is called 3rd generation wireless technologies.

[11] Please note that providing broadband on wireless is quite a hot area of research nowadays

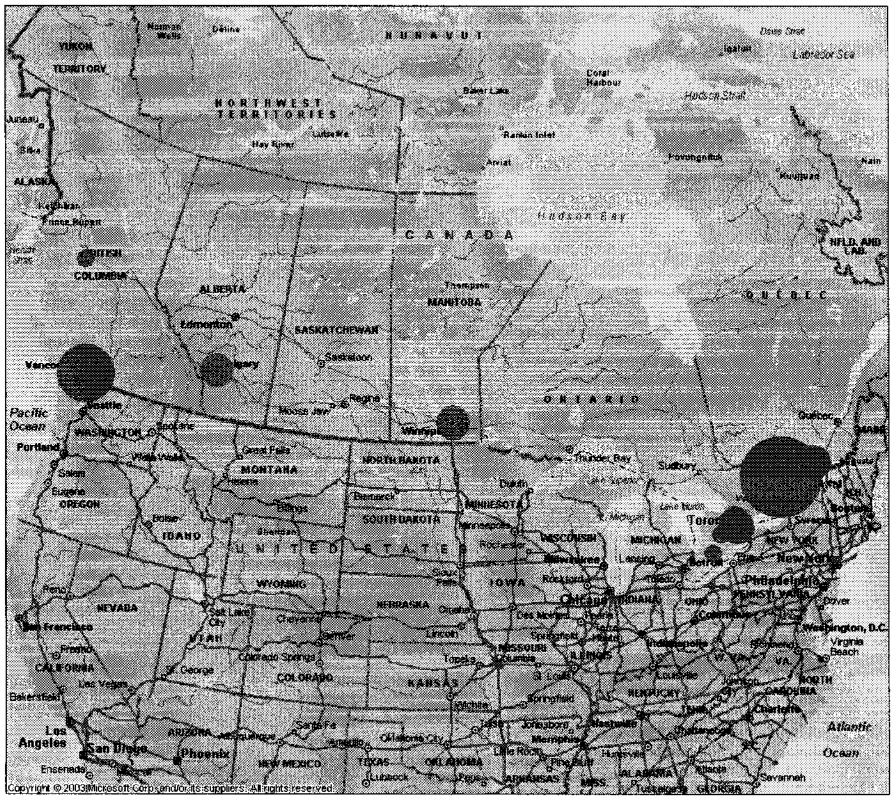


Figure 4.4 Number of TEM Firms Producing Broadband tech. per cluster map

Figure 4.4 spots firms producing broadband technologies throughout Canada. Bubbles size is arranged according to the number of firms in certain cluster.

4.1.3 Wireless Technology

We have identified 58 firms that produce wireless communication equipment. Out of these 58 firms, 38 firms are located in Ontario that is more than 65% of firms all over Canada. Quebec hosts 12 firms specializing in wireless technology, which is around 20% of the studied sample of firms. The remaining 15% of firms are scattered in British Columbia, Manitoba and Alberta. Average age of Canadian firms is 21 years.

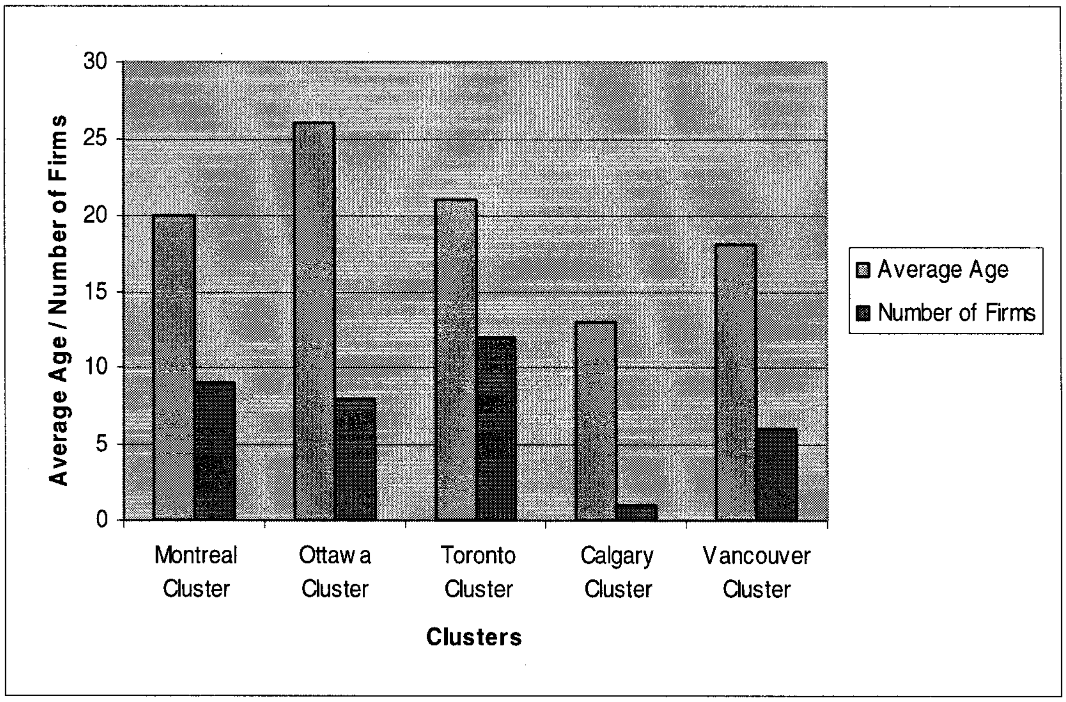


Figure 4.5 Wireless Technology Clusters

Figure 4.5 shows the distribution of firms that produce wireless technologies, with the Toronto cluster taking the lead, followed by Montreal, Ottawa, Vancouver and Calgary.

While only hosts 12 firms out of the 58 firms are located in Quebec, Saint-Laurent takes the highest share of firms specializing in wireless. In descending order, 7 firms are located in St-Laurent, 5 in Kanata, 4 in Markham and 3 in Ottawa.

As referred to earlier, this apparent specialization of Montreal in the wireless technologies could be due to the existence of Western Electric (later Nortel) which is considered an early incumbent in the voice technologies which dates from the beginning of the century in Montreal. Montreal also encouraged new comers like Ericsson, which holds an astonishing number of patents targeting wireless technologies as we will see later.

In figure 4.5 we can see that the main 4 clusters, Montreal, Ottawa, Toronto and Vancouver, are competing fiercely. The high relative age of firms, means that generally, firms in that domain are firms with an expertise in different domains, like voice communication, wireless research so on. This severe competition could be explained by the current demand for wireless services stimulated by end users. Of course this demand is indirectly transmitted to telephone operators that need to acquire high end level of products. This demand is produced by end users, demanding low end products such as mobile phones and other wireless devices to receive services from operators.

The Vancouver cluster comprises 5 firms, 3 located in Richmond, 1 in Vancouver, and 1 in Burnaby. It is remarkable that in 1993, 3 firms entered the Vancouver cluster: Arkon Networks provides wireless devices; Sierra Wireless, located in the Richmond Area, produces wireless data communication equipment; and Telos Engineering manufactures wireline, wireless and optical switching solutions, and was later acquired by Utstarcom.

Now let us take a closer look at firms. Saint Laurent in the Montreal cluster hosted SR Telecom, Mux LAB and Speedware Corp; three firms that produce wireless internet access software, EMS Technologies that produces satellite and wireless communication, and SYSCAN International Inc.

As for Kanata-Ottawa, it hosts 5 firms; The first entrant was Mitel Corporation, founded by 'Terence Mathews' an entrepreneur who originally founded Newbridge Network, later acquired by Alcatel. We see the same phenomenon that occurred in Fiber technologies occurring once again in the wireless technologies: an entrepreneur establishes a firm (Newbridge) specializing in broadband that is later acquired by Alcatel which benefited from this product line. In the meantime the same entrepreneur establishes another firm, the famous Mitel that specializes in wireless products and in networking, telephony products, and 4th generation technologies (4G)[12].

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[12] For more information on the 4th generation wireless technology please see chapter 2.

In 1979, Jatom systems established their offices in Kanata, the company specializes at providing wireless and data networks solutions. In Ottawa, we have identified 3 firms that produce wireless technologies; EMS technologies Canada founded in 1974, ZARLINK Semiconductor inc. specializing in analogue wireless systems and founded in 1971, and finally International Datacasting.

While Toronto city as such hosts a relatively low number of firms, working on wireless such as Waverider communications, the surrounded geographic areas, Mississauga, Markham, Oakville, Richmond Hill, Stratford (80 miles) and Waterloo (57 miles), are all populated by highly competitive firms. AZCAR Technologies Incorp was established in1981, followed in 1984 by CYGNAL Technologies Corporation both of which provide designs of wireless and wired communication networks. In 1987, Kaval Wireless technologies entered the cluster, producing wireless communication networks, and was later acquired by PowerWave Inc. Finally the latest entrant (in 1988) was Unique Broadband systems, currently a specialist in the design and manufacturing of wireless broadband solutions. In Mississauga, Nortel established a branch, Ericsson followed in 1982, and finally TEKLOGIX International Inc. The latter produces wireless data communication systems for corporations with a mobile workforce. Richmond Hill area hosts AIRSURF Networks a manufacturer of wireless LAN products established in 1986. Waterloo hosts mainly 2 firms: FINLINE Technologies, founded in 1989, produces multipoint multichannel distribution systems, and Research In Motion Limited, a pioneer company in wireless communication solutions was founded in 1984.

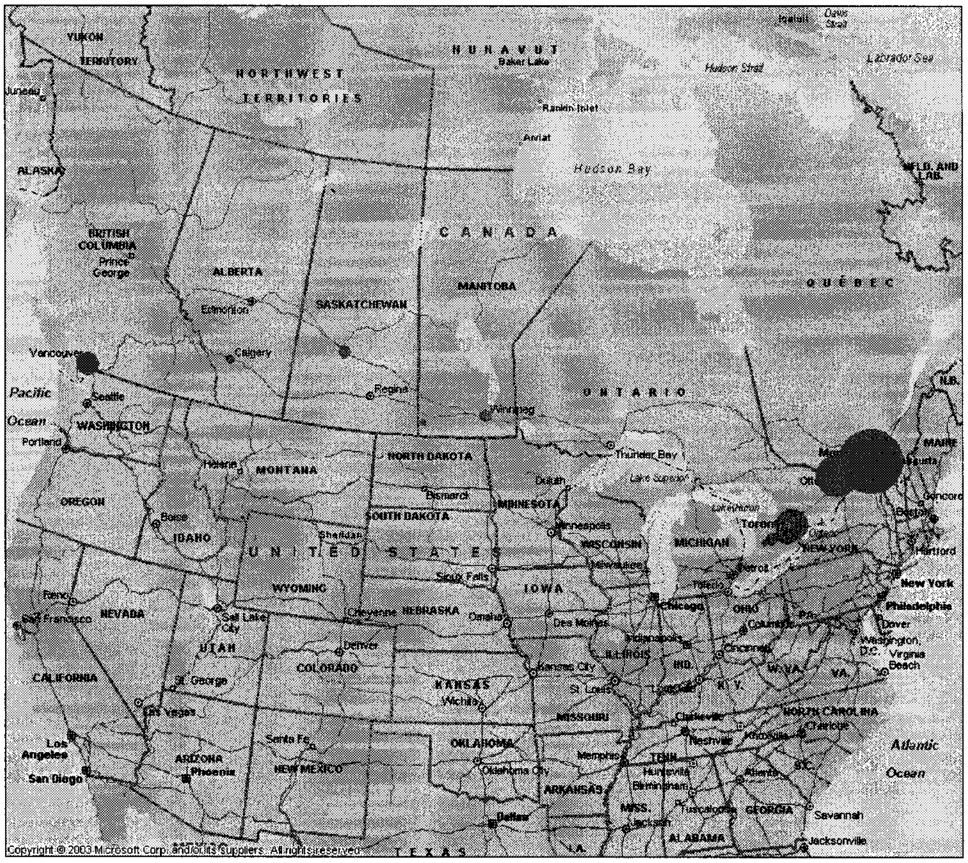

Figure 4.6 Number of Firms Producing wireless technologies per cluster

Figure 4.6 spots firms producing wireless throughout Canada. Bubble size is arranged according to the number of firms in a certain cluster.

4.1.4 Voice over IP technology

It is important to note that while the spectrum of firm's age is quite different in different regions, some of these firms managed to adapt to market demand while others did not. Figure 4.7 presents the average age of firms in the main five clusters. Of course, here, the average age of the firms, refers to the age of the firms that produce this technology at present, it is obvious that these firms did not produce such technologies at the time of establishment. These firms managed to adapt and to include newer technologies in order to survive and grow. Voice over IP is quite a recent technology; it could however be the future of voice messaging.

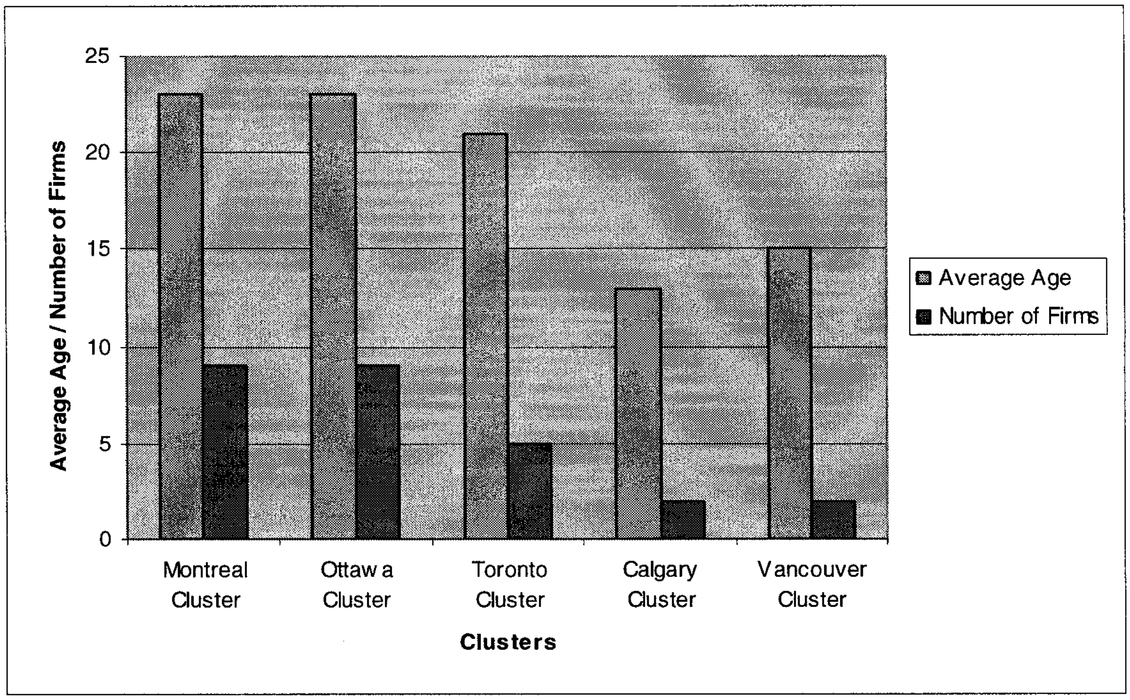

Figure 4.7 Voice over IP Clusters

Vancouver cluster hosts Microtel Ltd that was established in 1979 and PMC Sierra established year 1992. The Ottawa cluster hosts firms like Pika Technologies. Montreal cluster hosts Clarent Canada, started in 1989 and Memotec Communications started in 1993 in Longueuil. Saint Laurent hosts ABL Canada that produces voice, video and data communication equipment. Saskatoon used to host Develcon Electronics a firm that mainly specializes at IP routing, as well as voice and data integration.

Montreal and Ottawa are in the lead with respect to voice over IP technologies. While this technology is still a young one, it could however be the basic mean for future communication due to its low cost and its seemingly increasing quality. Of course if such a technology is properly commercialized, it could be a substitute for the traditional voice communication that we currently use. The usage of voice over IP is currently adopted by larger enterprises to connect its various offices with lower cost, on their data networks. There is a current trend of providing this service to satisfy residential needs. Firms like Vonage are an example of such service providers that offer VoIP services to the different business segments. Of course such a service is a threat for telecommunication operators, especially for international calls services. This is why telecommunication services operators could be declaring a price war against these technology providers or trying to acquire them as soon as possible especially for international calls services which is very expensive if compared to VoIP services provided by firms like Vonage.

Figure 4.8 Number of TEM Firms Producing VoIP technologies per cluster map

Figure 4.8 spots firms producing VoIP throughout Canada. Bubbles sizes are arranged according to the number of firms in a certain cluster.

4.2 Patenting output

In this section we will investigate the innovative capacity of clusters, and the CTEMs industrial agglomerations. Since we are primarily concerned with the technological evolution of these clusters, we have segmented telecommunication manufacturing innovation into 5 main products or technologies: fiber technology, telecommunication services, software management, voice, and wireless. The main source of the data provided in this section is the Canadian Patents database. Each technology will be addressed in terms of the following aspects:

- Location, to examine whether there is any innovative output concentration linked with a specific technology;
- Evolution in the number of patents produced on the Canadian level, to understand the dynamics of each technology;
- Evolution in the number of patents produced by major clusters to examine whether there is any kind of specificity relevant to location and how does this evolve with time.

Our main task here is to identify technological trends rather than search for exact numerical analysis for the data. While identifying these technological trends, a major problematic arose: Patents are segmented by technology using different keywords. If these keywords match the patent description in our database, the technological trend is established. However, if this link is not established, a trend is not identified. Not identifying a keyword in our database, does not necessarily mean that the trend is not there. For instance, if we plotted a number of patents in wireless technology in year 1999, then we identified zero patents in wireless in 2000, followed by another number of patents in 2001, we assume that there is a linear increase or decrease. This assumption is quite logical given the fact that technologies are quite complex in nature, that a patent description might not include the keyword used for our search. For example, the technology segment for a patent addressing an amplifier used in a modem for example, might not be identified as such, in its patent description field, and therefore if we put a zero patent in our analysis, we might not be getting the correct trends.

4.2.1 Fiber Technology

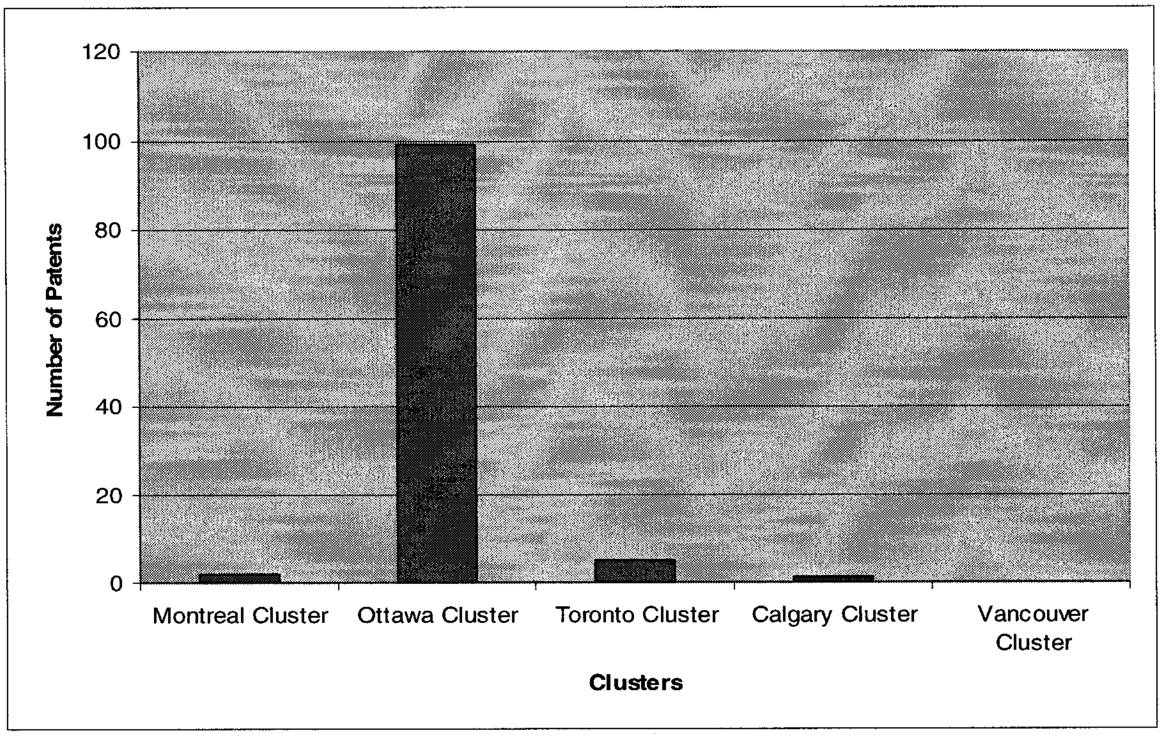

Figure 4.9 Fibre Patents per Cluster

Figure 4.9 shows that fiber technology innovation is mainly concentrated in the Ottawa cluster. The majority of fiber technology patents are owned by JDS Uniphase, and Fitel (previously) in the Ottawa region, and some by Research in Motion in Waterloo. It is important to note that such trend was somewhat expected from the industry structure of Ottawa as studied previously, where almost all firms have a higher relative age and spend huge amounts in R&D required to advance research in a highly expensive domain such as fiber technologies.

Figure 4.10 presents the evolution of the number of patents, related to fiber technology. Note that fiber technology is not a recent innovation. This breakthrough innovation dates back almost 50 years. In the late seventies and beginning of the eighties, it was supported by incumbent firms like Nortel Networks (Northern Telecom then).

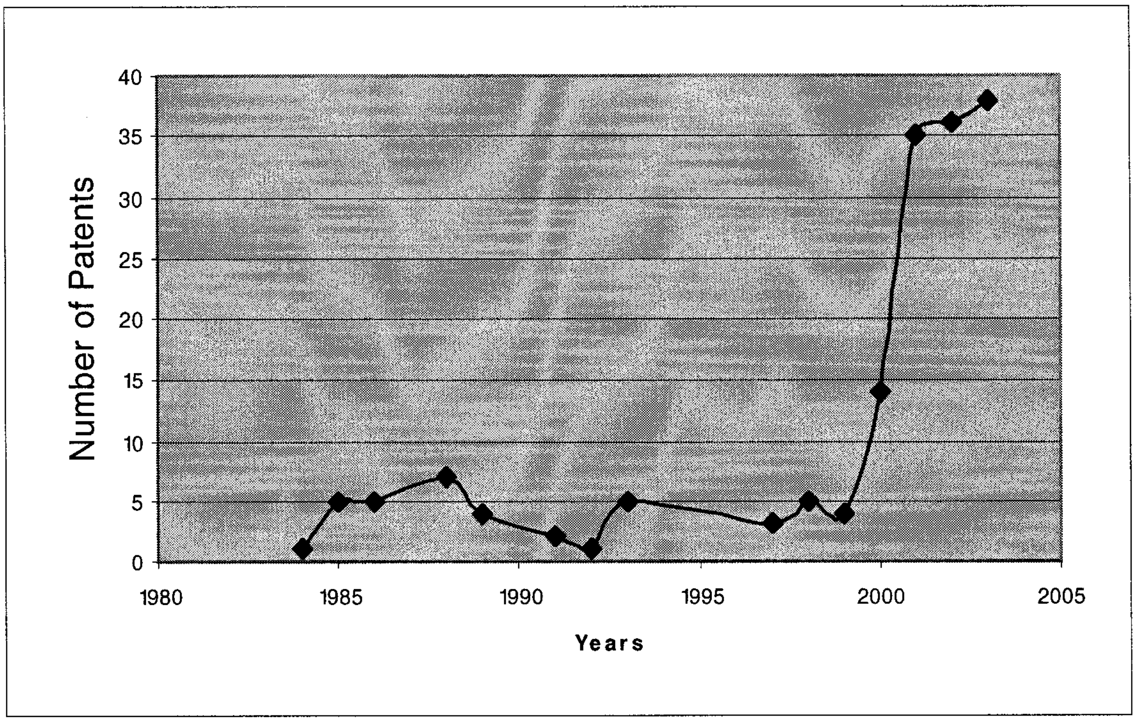

Figure 4.10 Number of Canadian Fiber Patents

Currently however we are witnessing incremental innovations from firms to deploy fiber technologies commercially. As seen in figure 4.10 the evolution of patents in that domain began to increase rapidly since 2000. Demand pressure on fiber technology innovations materialized with the rapid increase in demand for highly intensive media, and data transmission across data networks. This is why we can see on the graph the remarkable innovative growth that this technology is witnessing. Demand for higher bandwidth became inevitable, not only due to demand on media data transmission, but also to the excessive demand for putting voice onto data networks (i.e. VoIP).

This convergence of technologies previously explained in Chapter 2, is putting more pressure on increasing bandwidth infrastructures, and this in turn, has stimulated more innovative activities in this area of technology.

Figure C.1 in annex simply demonstrates that almost all the Canadian innovative activities in the fiber technology domain are located in the Ottawa cluster, furthermore, the regions of Nepean, and to a lesser extent Ottawa city, are the main drivers behind the witnessed growth. Vancouver, Montreal and Calgary, almost did not contribute to the innovative activities in the fiber technology, with the exception of a small contribution from Toronto (see figure C.2).

While the scale of contribution of the Toronto cluster is still negligible if we compare it to that of the Ottawa region, there is an important remark that we can draw from figure C.2 regarding the rise of the Waterloo contribution with respect to fiber technologies. The rise of the innovative output for the region of Waterloo is due to the existence of the firm 'Research in Motion' that is a leader in wireless devices, however started to patent in the fiber domain lately.

Firms specializing in wireless technologies are realizing the importance of high bandwidth provided by fiber technologies, and hence they should start to diversify their output, to capitalize on both the new technological trends in wireless and fiber technologies. We also can see that Brampton where Nortel headquarter is located and holds the majority of their work force, did not add any contribution to the Toronto region in the fiber technology patents and this consequently demonstrates that while Nortel is a main producer of fiber technologies, its main innovative output sources from its office located in the Ottawa cluster, not from Toronto which primarily focuses on sales and marketing activities.

4.2.2 Telecommunication Services Technology

In this section, telecommunication services include all types of devices or software that helps operators provide services to their clients. There are two important remarks we can draw from figure 4.11; first, Ottawa cluster still remains a leader in terms of innovative output. Second, we can see here that while in the fiber technologies, Ottawa is almost an innovative monopoly, other clusters started to contribute significantly to the telecommunication services innovation side. Montreal, Ottawa, Toronto, Calgary and Vancouver clusters all contributed to the resultant innovations in the segment. Local demand induced by the rise of telecommunication operators located in all major cities could be the main driver for this increase in innovations.

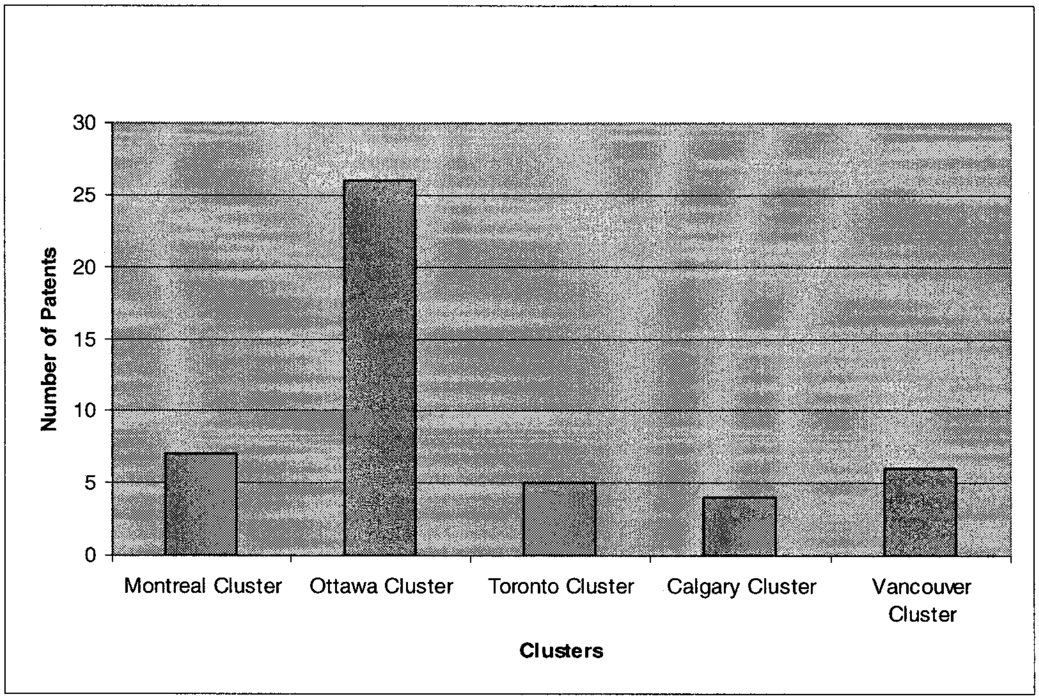

Figure 4.11 Telecommunication Services Patents per Cluster

While the IBBB did not significantly affect the innovative product in the fiber domain, the telecommunication services domain seems to have been highly affected. Innovative output has accelerated exponentially from the mid 90s to 2001, to drop sharply in 2002.

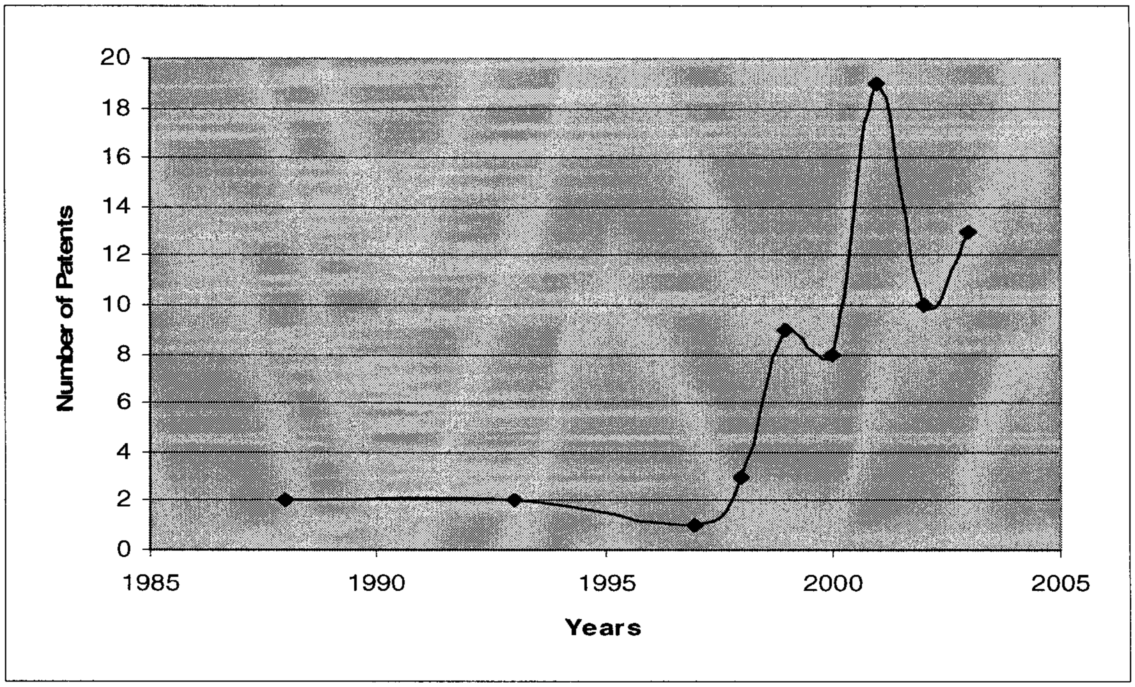

Figure 4.12 Canadian Telecom. Services Patents

Figure 4.12 shows that the effect of the IBBB became visible in 2001, where innovative output in this sub-sector dropped from 18 to 10 patents. An intuitive explanation for this, is that demand produced by operators dropped on such products temporarily, which had obliged technology vendors to reduce the pace of innovation in that domain. The trend seems to be picking up however, and operators are currently looking for newer services to satisfy their clientele.

If we take the five main clusters into perspective, figure 4.13 shows that Ottawa seems to be leading by far with a relatively small contribution from the other regions and that the effect of the IBBB is more evident in the Ottawa, Toronto, and Vancouver clusters.

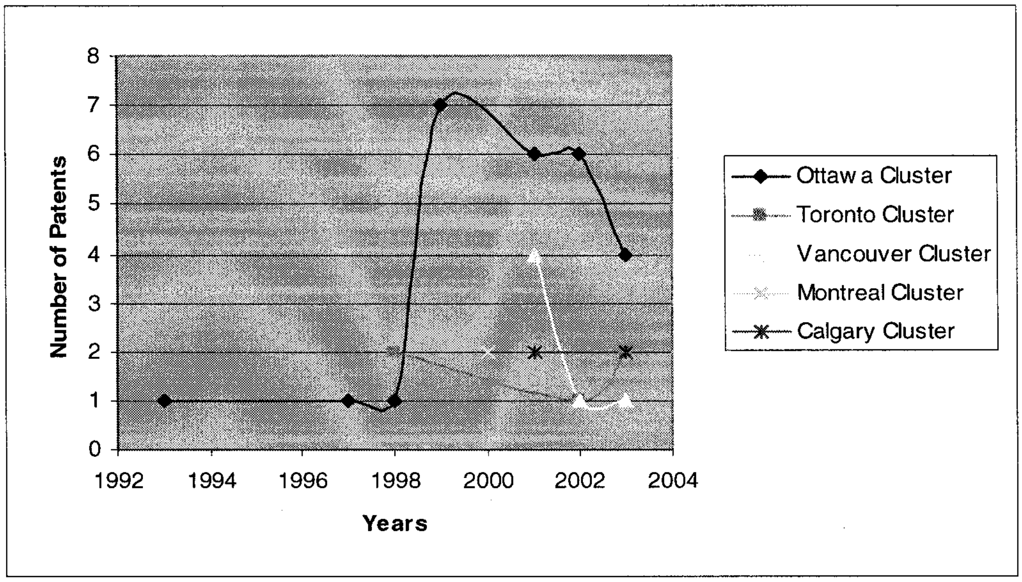

Figure 4.13 Telecom Services Patent Evolution

Figure C.3 in annex shows that the main contribution in Ottawa is mainly driven by Nepean, followed by Kanata, while Ottawa city seems to be accelerating with a slower pace, but leads over Nepean and Kanata lately.

4.2.3 Telecommunication Software Management Technology

Software Management Technology here denotes all software that is used to manage telecommunication networks. Figure 4.14 provides the distribution throughout the five identified Canadian clusters that produces inventions in that domain

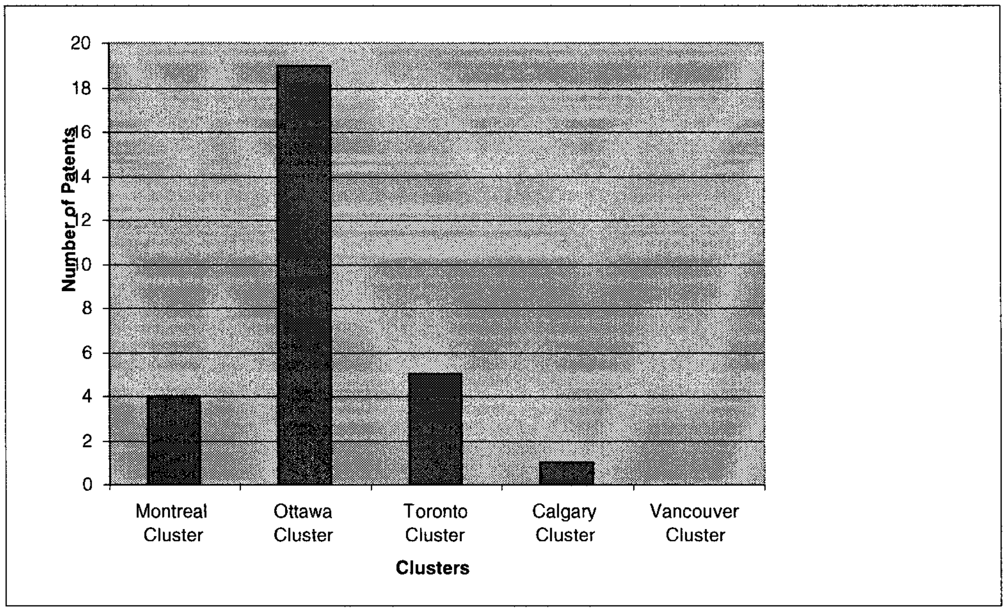

Figure 4.14 Telecom. Software Management per Cluster

As expected, the Ottawa cluster still takes the lead, followed by Toronto and Montreal. While the Ottawa region attracts labor that excels mostly in highly advanced, hardware engineering innovations, Toronto city seems to be highly capable of producing more software oriented telecommunication innovations. While labor specialization seems to be mandatory in regions like Ottawa in order to advance highly technical hardware innovations, this kind of specialization is not needed as much when it comes to software. This is due probably to the relatively less expensive R&D associated with software innovations in comparison to hardware in this particular domain.

Figure 4.15 shows the evolution in the number of patents addressing telecommunication software management on the Canadian level. The figure shows that telecommunication software management innovations are gaining importance with time. Beginning in the mid 1990s, the flow of inventions has increased tremendously to reach its peak in 1999-2000.

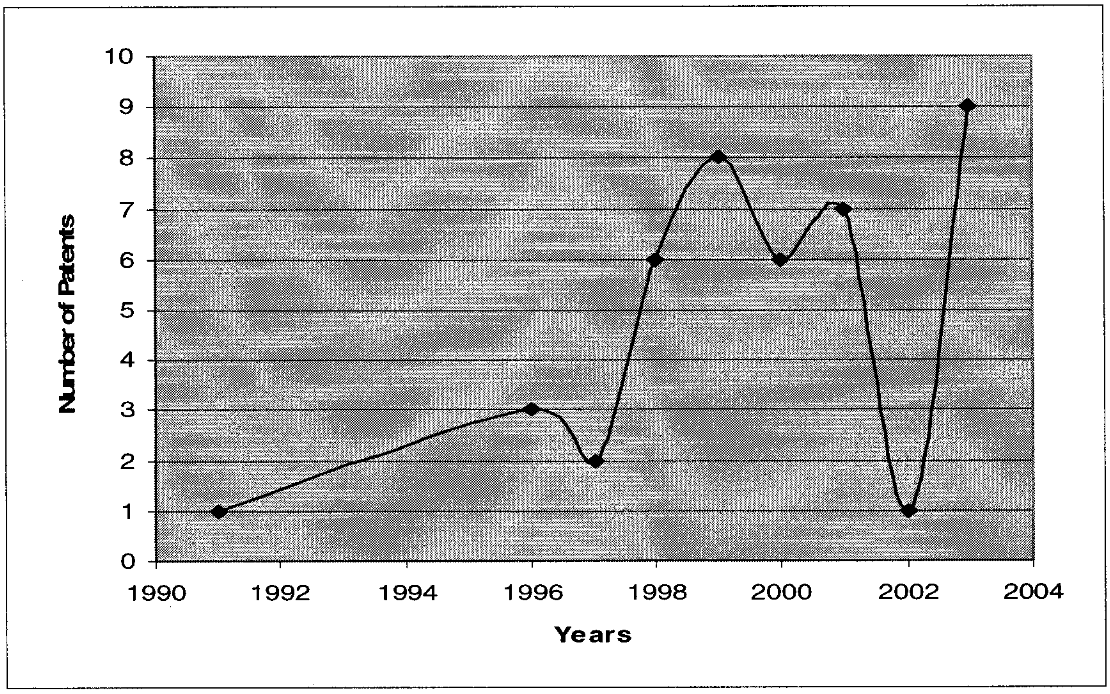

Figure 4.15 Canadian Telecom Software Management Patents

The effect of the IBBB on innovative output in that sector seems to be significant, where the number of patents dropped to only 1 patent issued year 2002. The innovative capacity in that technology however seems to be exploding to reach an unprecedented peak in 2003-2004. This current boom in telecommunication software management innovation is of course led by the increasing demand on networks, which consequently puts more pressures on firms to produce more complicated software to manage these highly complex networks carrying different media, and addressing users with different needs. It seems that the current trend of providing higher bandwidth (provided by fiber for example) is coupled with an increasing demand from operators for software management tools to help them manage the current unprecedented demand on their networks.

Figure C.4 in annex shows the contribution of Ottawa to the telecommunication software management. Figure C.5 in annex demonstrates that while Toronto and Ottawa regions were on equal foot in 2000, Ottawa region seems to be keeping up the pace, while Toronto region is struggling to keep up.

4.2.4 Voice Technology

Voice technologies here include analog and digital technologies, so it includes innovations such as normal voice switching used by landline telephone operators but also voice carried on data networks (VoIP).

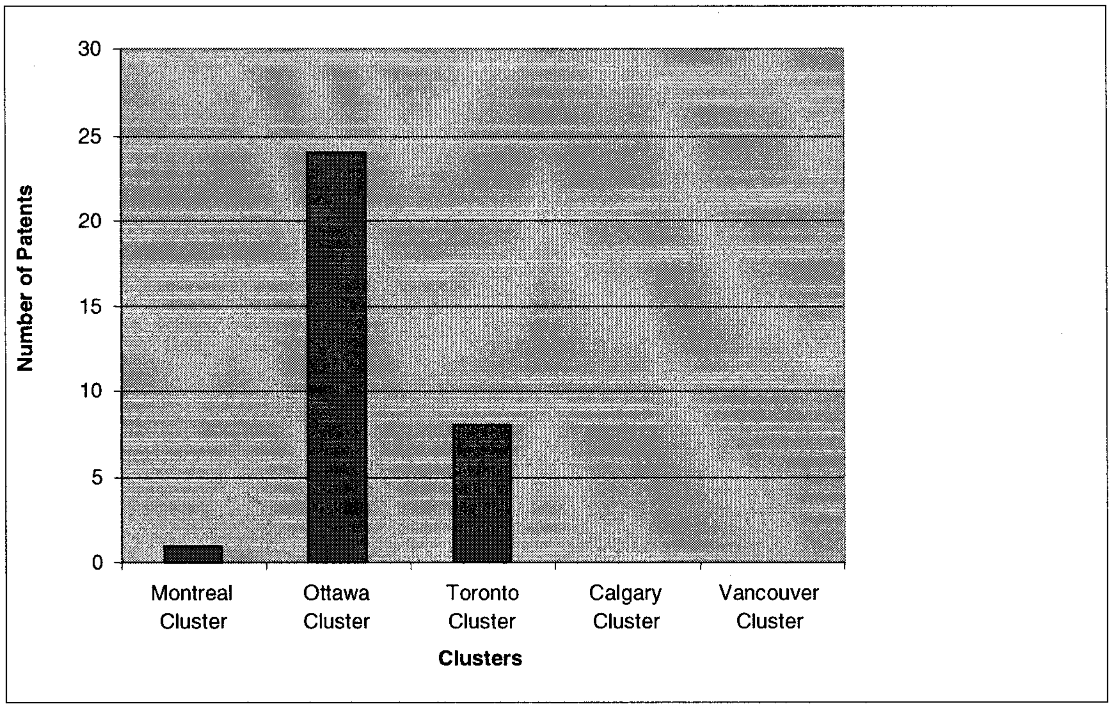

Figure 4.16 Voice Technology Patents per cluster

Figure 4.16 shows that the lion share of innovation in that domain is the Ottawa cluster, followed by Toronto cluster. This is of course is driven by firms like Nortel, Mitel and Alcatel located in Ottawa and who specialize in voice transmission technologies since its early days. Of course one of the main competitive advantages of Ottawa is the convergence of telecommunication technologies. Ottawa is the only diversified cluster among all other clusters, with a diversified pool of skilled labor that can enable firms to adapt with the current convergence in telecommunication technologies.

Figure 4.17 shows an interesting phenomenon. First we notice a negatively sloped line that has its peak in the mid 80s. After 2000, however, patenting shows an upwards trend that reached its highest peak ever in 2004.

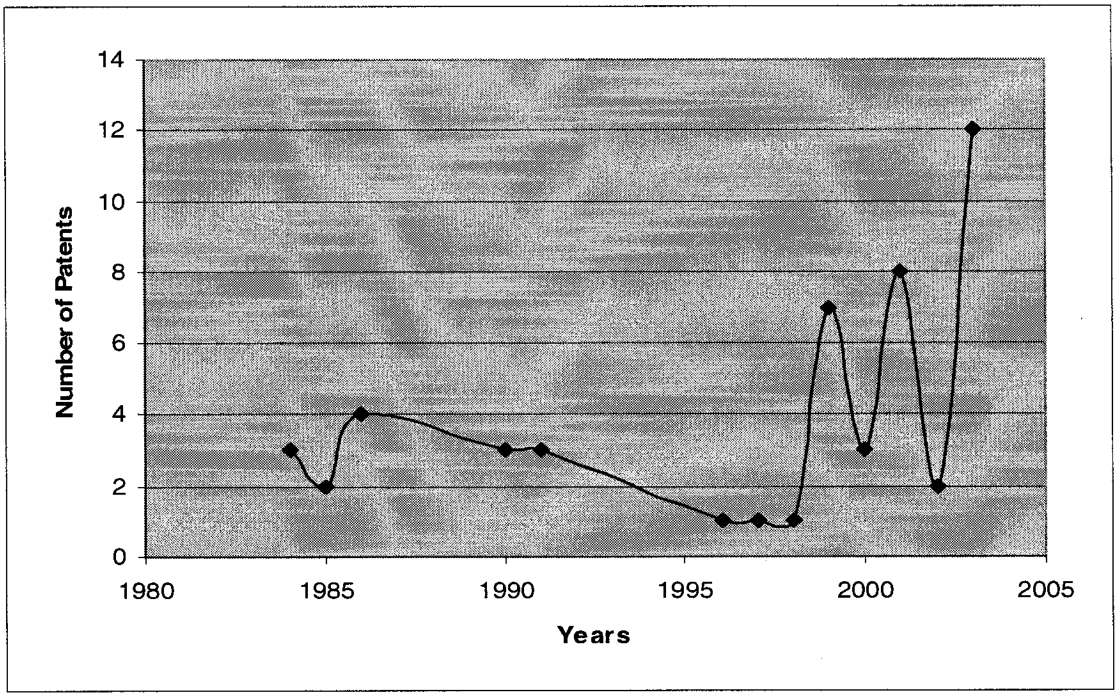

Figure 4.17 Voice Patents Evolution

A viable explanation of this phenomenon is the following: The mid to late eighties were characterized by data network explosion, when the internet was opened for public utilization. It seems that while the market was striving for innovation on the data networks part, less innovation was needed on the traditional voice switching side, for instance innovations to perform normal dialup between switches and different locations. Due to this technology shift, the number of patents that target voice networks diminished, at the same time that more innovative output was produced on the data communication side. Lately, due to the technology convergence, skills needed to develop voice products have become more important, and innovative output related to voice, and its integration on data networks known as VoIP is regaining its importance. In other words, the product life cycle for normal voice switching became stable, and actually began to decline until the mid 1990s, when until that time the technology to a great extent was almost saturated. With the current technological trend of network convergence however, the product life cycle for voice communication began to regain new grounds but in another form, VoIP.

Figure C.6 in annex and 4.18 presents the main cities that contributed to voice innovations. The Ottawa cluster is once again in the lead in from of Toronto.

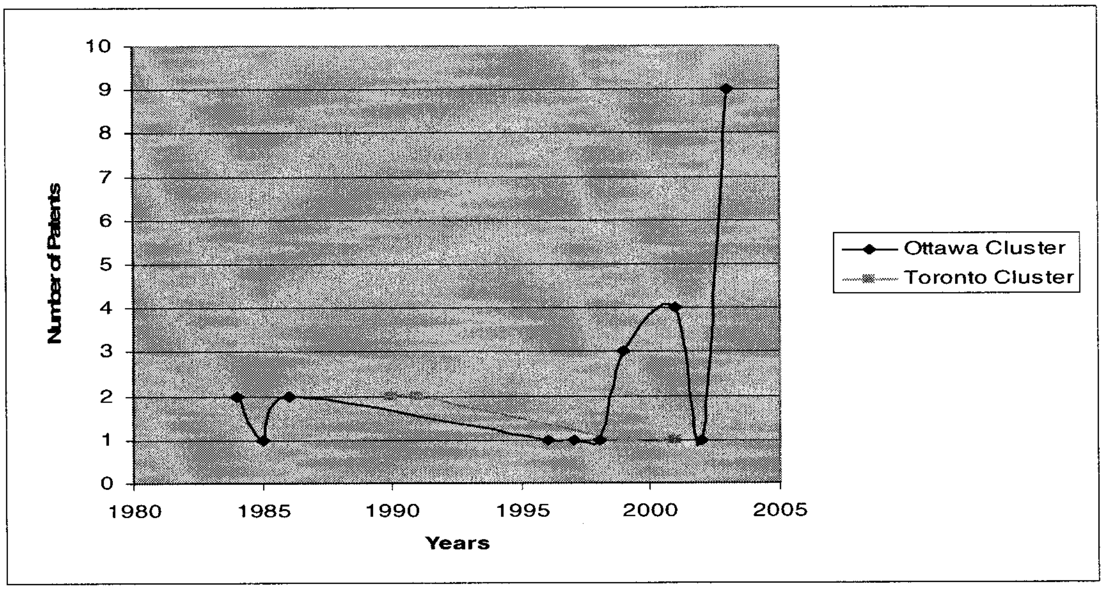

Figure 4.18 Voice Patents Evolution

It seems also that while Toronto and Ottawa were in competition with respect to the voice technology until the mid 1990s, Ottawa has gained the upper hand lately. This could be explained by the specialized labor in data communication located in Ottawa and who provides the region with the necessary competitive advantage to contribute to the new technological shift and network convergence.

4.2.5 Wireless Technology

Figure 4.19 shows how widespread the wireless technology is, with respect to Canadian clusters.

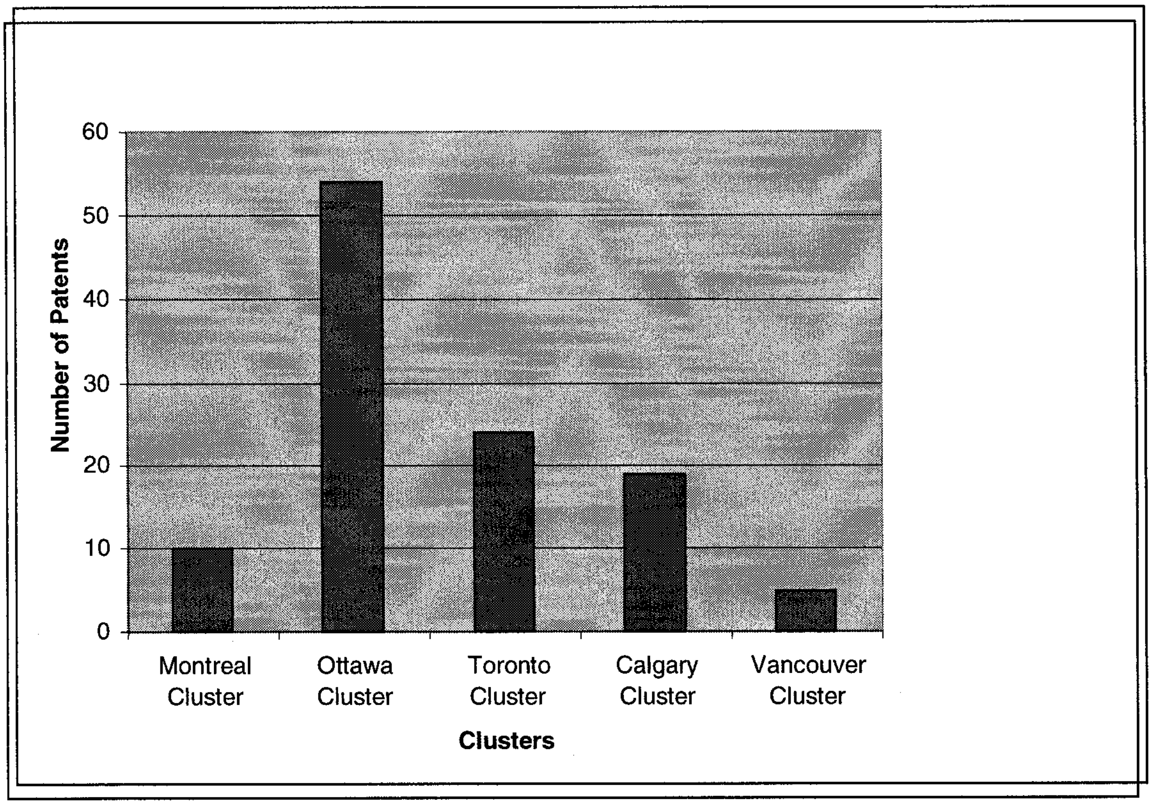

Figure 4.19 Number of Wireless Patents (Per Cluster)

As ever, the Ottawa cluster take the lead, followed by Toronto and Calgary, a previous host for Telus Telecommunication. This could probably explain why Calgary is somewhat advanced in wireless technology innovation. While the same argument is valid for Montreal where Bell Canada is based, the majority of the patents produced in Montreal in the wireless technology are held by Ericsson. Of course Waterloo still keep its leadership in this particular field, due to the firm 'Research in Motion' a producer of wireless devices, such as the blackberry product.

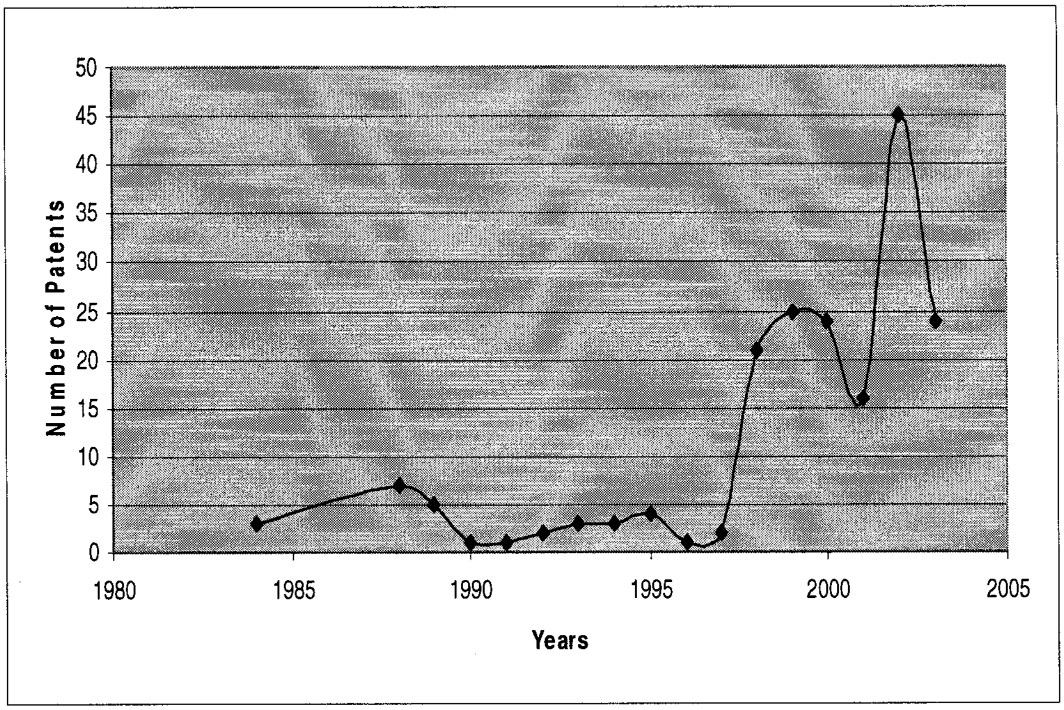

Figure 4.20 Canadian Wireless Patent Evolution

Figure 4.20 shows that, while wireless innovative output kept a low profile from the beginning of the 1980s until the mid 1990s, this profile absolutely changed recently. Starting in the mid 1990s the slope of innovative protection activity is increasing rapidly. Of course this is due to the rapid deployment of mobile communications, whether voice or data.

This shape of innovations targeting the wireless technology could be understood as follows; while the technology started to be exploited, the number of innovations was low, but probably held breakthrough innovations. The number started to increase with incremental innovation that grows as the technology is commercialized and marketed to operators as well as end users.

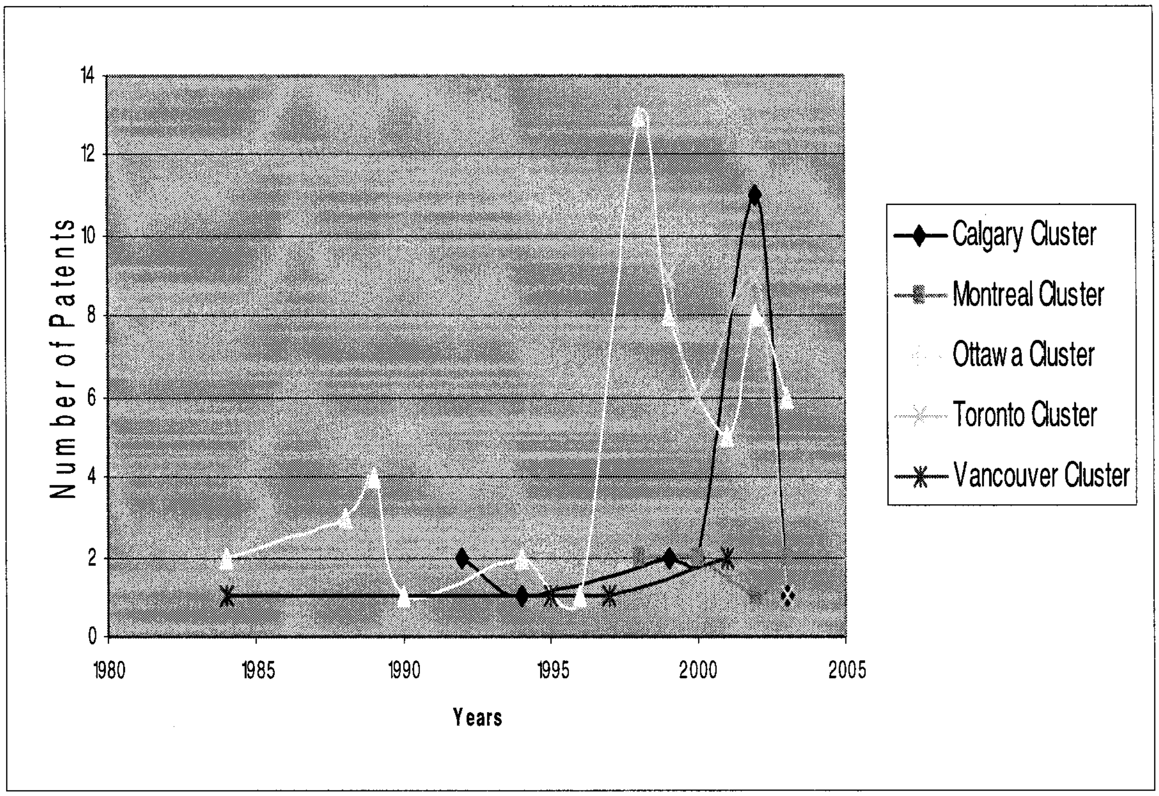

Figure 4.21 Wireless Patent Evolution (Per Cluster)

Figure 4.21, demonstrates the contribution of each cluster to the patenting evolution. Of course we can see that Ottawa is the main leader contributing to wireless, however, Calgary lately entered the competition. As previously explained, the boom in the wireless technology, started to rise in the mid 1990s, and ramped up, until the IBBB, but the trend is still heading upwards. The main noticeable remark we can draw here, is that the wireless technology is the only technology that witnessed such a competition, between different locations from the Canadian east to the west coast. Of course the main reason for this is the current deployment of wireless services by widespread operators, that offer mobile services for their clientele, a technology that became almost indispensable for the majority of the end-users nowadays.

4.3 Universities, firms and Technological trends

Out of more than a thousand patents we have identified 17 patents owned by Canadian universities.

Table 4.1 Universities and Number of Patents

Universities	Number of Patents
Ottawa University	4
Sherbrooke . University	3
Queen's University	2
University of British Columbia	2
Dalhousie University	1
Saskatchewan University	1
Laval University	1
Ryerson Polytechnique and University of Toronto	1
Dalhousie University	1
Waterloo	1

Table 4.1 shows that, Ottawa University takes the lead in terms of the number of patents issued, followed, by Sherbrooke, Queen's and University of British Columbia. However, the ratio is still very small; only 1.5% of the Canadian patents issued in the telecommunication are owned by universities.

This result is not surprising however, firms in the Telecommunication Equipment Manufacturing (TEM) sector are the main contributors to innovation, especially since with time, incremental innovations in this field increasingly require a tremendous amount of R&D investment, that universities are not capable to provide. Therefore, in the TEM sector, firms are the main attractors of scientists from universities, not the opposite. It is a common trend that scientists from universities in this domain, collaborate with firms. And while the government provides university researchers and scientists with research funds, a great proportion of financing is usually obtained from firms, and in general the industry itself.

Firms, with time, have increased technical and financial barriers to entry in that area of research, and this is why researchers, often, for that reason work with the industry.

Meanwhile, the government encourages scientists to follow that track of collaboration between universities and the industry. For instance, if professors and scientists are capable of receiving industrial grants, the government grants an equal amount to the scientists to build research teams, and this further enhances collaboration between universities and the industry. This is a win-win strategy, where scientists are capable of benefiting from labs in firms, and train younger researchers as well as fund them, while firms, obtain high quality research with a negligible cost, compared to in house R&D scientists.

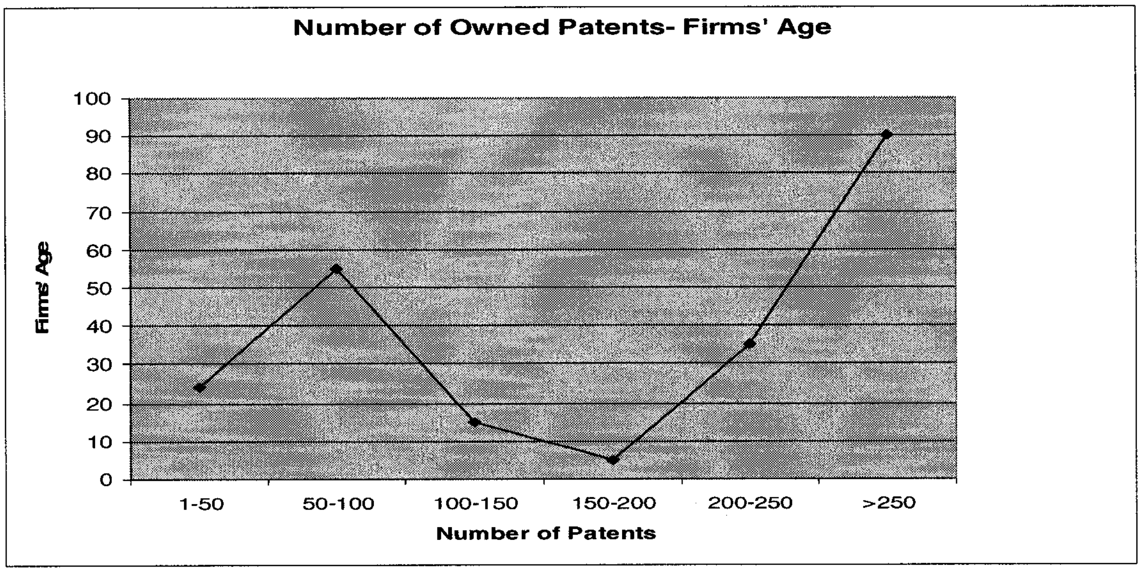

Figure 4.22 Number of Owned Patents & Firms' Age

Figure 4.22 shows the relation between firms' age and patenting activities (Extracted from our patent database) in Canada. From this figure we can see that generally those two categories of firms are producing patenting output. Old firms with more than 90 years of activity, in other words Nortel, which managed to survive the different technological shifts and capitalize on them. It is worth mentioning that Nortel holds almost 40% of the total number of patents produced in the Canadian telecommunication market. The second category is relatively younger firms, established between 5 and 20 years ago like Mitel, Research in Motion, Ericsson Canada.

According to a survey led by Research Info Source Inc. (2001), when trying to classify the top Canadian R&D spenders, telecommunication equipment manufacturers accounted for 19 out of the top 100 Canadian Manufacturers[13]. Not only did the Canadian telecommunication industry occupy almost 20% of the top R&D Canadian spenders list, but Nortel was also ranked number one in R&D spending amongst other heavy R&D spending industries such as Aerospace, Energy and Biotechnology firms. JDS Uniphase takes the second position and Ericsson Canada is in the fourth position.

Incumbent firms in the telecommunication industry seem to enjoy high protection from entry; the main competition in that industry however is basically between established firms who strategically need to market their technologies. Competition and changes in the market structure therefore have an international nature. As highlighted by Standard and Poor Survey (2004), major companies basically dominate the market of telecommunication equipment. Therefore market structure changes might not be as obvious as other technologies (semiconductors, and biotechnology), however on the international level such changes are quite clear.

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[13] Note that the manufacturing industries mentioned in the report included the Aerospace, Computer, Software, Electronics, Mining and Metals, Energy, Biotechnology, Oil and Gas, Health services, Electrical Power, Machinery, Medical Devices and the Transportation industries

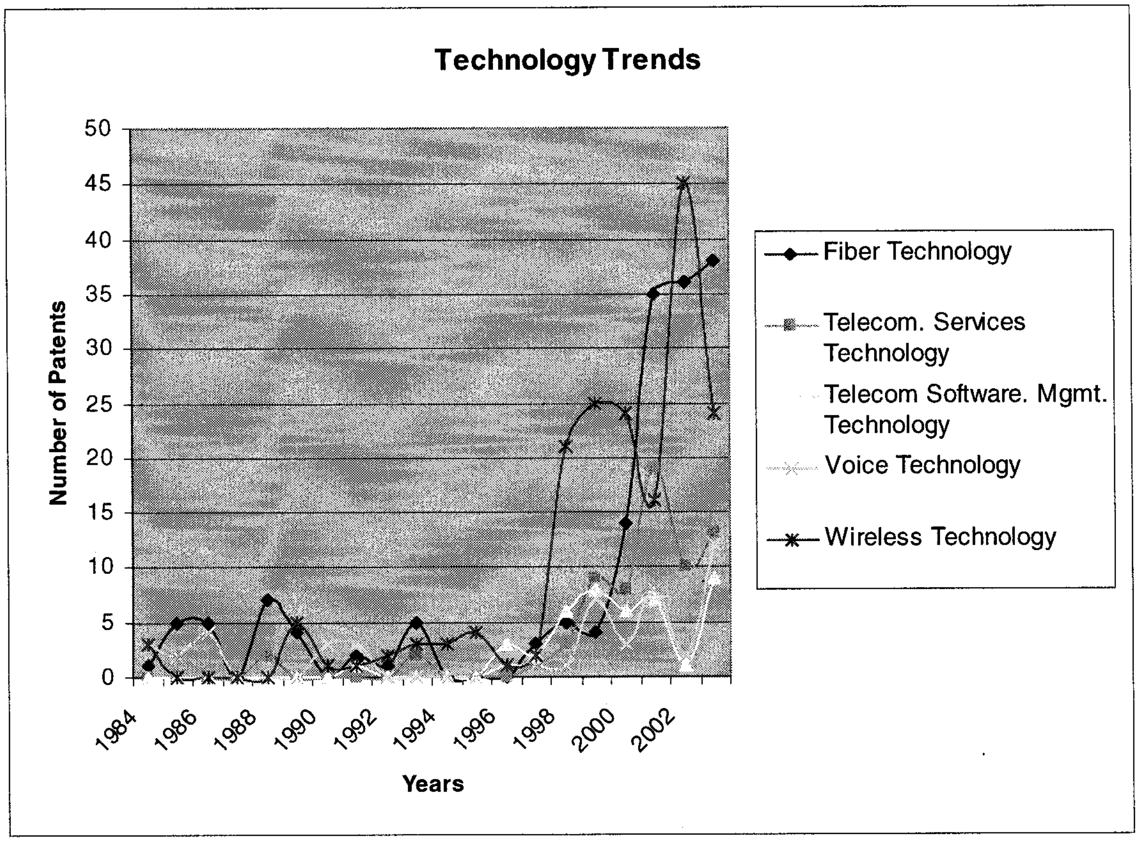

Figure 4.23 Technology Trends (Derived from Patents)

In figure 4.23 we have gathered the 5 technologies studied in the patenting section. The graph demonstrates the trends of the different technologies when compared to each other.

The main two booming technologies are mainly wireless and fiber technologies. Both of these technologies are supported with advancement in high end products or low end products, and this has been demonstrated in the telecommunication services technology section. The figure also demonstrates the latest advancement in software management innovations aiming at controlling the currently highly complex networks from the operators' side. We also have presented the current technology shift that voice technology is witnessing which is primarily due to the emergence of the Voice over IP technology providing voice calling services on data networks.

4.4 Conclusion

On the technology side, we can notice that the degree of technology specialization is different among cities. This could be seen on both firms' activities and patenting activities, in the various regions studied.

The Ottawa cluster seems to take the lead by far from other regions in the fiber technology field. On the broadband and wireless technology side, firms' activities seem to be active in different regions, namely: Toronto, Vancouver, Ottawa, Montreal and Calgary. Of course this is mainly driven by the increasing demand from end users for wireless and media communication. It is also remarkable that the VoIP, as a newly introduced technology, is still gaining ground; we cannot therefore determine yet any kind of relation between technology and location.

The Ottawa cluster seems to be dominating with respect to patenting activities targeting different telecommunication technologies. This has contributed to increase the barriers to entry. Another region that seems to be very active with respect to patenting is Waterloo, mainly driven by the firm Research in Motion that patents in both wireless technology (its core competency) and in fiber technology, probably aiming at diversifying its product portfolio.

Big clusters such as Vancouver, Montreal, Toronto, Ottawa and Calgary contribute to patenting on the services side, and this is driven mainly by demand from operators scattered geographically in each region. With time, patenting activities with respect to telecommunication software management seems to be remarkably accelerating, driven mainly by the Ottawa region.

The current technology convergence, is now putting more pressure on the software layer to control network traffic, and put more security on networks. Also we have seen that voice technology is currently witnessing a remarkable advance, due to the emergence of the VoIP technology. The same phenomenon was witnessed in the wireless technology that became almost mandatory as a mean for telecommunication.

Generally, while big financial cities, Toronto and Montreal hold the majority of headquarters for manufacturing firms, innovative output is concentrated primarily in Ottawa followed by Montreal, Toronto and Vancouver.

On the firm level, early incumbent firms in the TEM industry hold the upper hand. In this industry firms' age played a key role in firms' survival. Early entrants in that industry have, with time, increased barriers to entry, keeping the door open only for very few firms that have breakthrough or radical innovations, otherwise, these firms exit and are not able to survive. A classic example of this is, Nortel a firm that have already invested in highly intensive R&D projects to increase barriers.

When examining Universities and their contribution to the innovative product in the clusters they reside, we have found that universities contribute minimally. Of course this does not deny the fact that Universities are a contributor to clusters innovative performance; however this is done indirectly through collaboration with incumbent telecommunication manufacturing firms.

CHAPTER 5 - SIMULATION

The prime goal of this chapter is to simulate the development of industrial clusters over time. Simulation has been widely used in economics to represent complex social systems that are very hard to describe mathematically. Section 5.1 presents an overview of simulation in economics. In section 5.2, industrial dynamics will be introduced as a tool to simulate social/complex systems. In section 5.3, the link between industrial dynamics, used for simulation, and evolutionary economics, will be developed. Section 5.4 will include a general description of the tools used in industrial dynamics simulations. In Section 5.5 the model used in the simulation will be presented. The model development phase will start by identifying the various factors or variables included in the model, the relation between different variables will be presented using causal loop diagrams, then the model will be developed to be simulated. Finally, section 5.6 concludes.

5.1 Overview on Simulation in Economics

Simulation is quite useful when trying to understand complex socio-economic behavior. The key advantage of simulations is that they are not bound by any constraints such as those of pure analytical methods (Nelson & Winter, 1982 pp. 208). When trying to model evolving dynamic systems, approaches such as simulation could be of a high degree of importance. Nelson and Winter highlighted that in orthodox modeling, the main emphasis is on equilibrium conditions; therefore time dependence *does not* hold a priority and is sometimes ignored.

Because of this, simulation in the field of Industrial Organization became a widely used tool for researchers. For example, Malerba *et al.* (2001) implemented a simulation model to understand the dynamics of competition and industrial policies, and its effect on the computer industry. The researchers targeted antirust, and intervention policies that aim at protecting new-entrants in a given industry. The proposed model takes into account several factors that affect companies' decisions. For instance, firms' pricing strategy is based on the R&D cost, as well as advertising expenses. Competencies of each firm are based on its engineers' abilities to develop incremental innovation to further enhance product competitiveness and hence the overall firm competitive advantage. In the simulation, the quality of the design is mainly based on the R&D capacity of a certain firm. And profits of each firm are calculated on each time slot. On the market dynamics side, differentiated products are sold into different segments of the market. Demand for those products is based on the product price and its performance. Customer's preference (or utility) is represented using a Cobb-Douglas function that includes the price and performance. Customers reach the decision of buying by choosing the higher level of utility achieved between two products. Simulations have shown that demand and the increase in technological opportunities highly affected the innovative performance of firms. After trying several scenarios, it is shown that, while on the one hand, the increase in the patent protection increased concentration, on the other hand, it decreased exploration.

In the same vein, Malerba and Orsenigo (2001) applied the history friendly model of innovation in trying to understand the market structure and regulations, and how they affect the pharmaceutical industry. In their work, patents have been included in the model (They were excluded from the computer model described above, Malerba *et al.* (2001)), since it is one of the crucial factors towards the development of products in that industry. In that domain, it has been emphasized that firms mostly have 3 activities, search, research and marketing. It is demonstrated that the difference between Innovators and imitators in such an industry is basically imitative activities and innovative ones. The utility, demand and market share are modelled similarly as in Malerba *et al.* (2001) model of the computer industry. The study shows that there is a low level of concentration in the overall market, and that innovative firms played a key role to foster the industry's innovative capacity. It also shows that the role of innovative firms is affected by demand growth and increase in technological opportunities. On the patents side, it is proved that with the increase in patent protection, concentration increases, but exploration decreases.

5.2 Industrial/Business Dynamics

System Dynamics foundation was developed by Jay Forrester, an electrical engineer at MIT who had interests in control systems. Forrester emphasized the role of simulation using control systems to simulate different phenomena. Those phenomena included simulating a 'world system' that includes population, birth rates, death rates, natural resource extraction, crowding ratio, food ratio, pollution, quality of life and capital investment (Forrester, 1971). Forrester (1969) also exploited the use of industrial dynamics to simulate structures of urban areas. In this study, Forrester (1969) studied employment, labor's birth rate, arrivals, housing construction and other diversified aspects that affect any urban system.

Referring to the basics of control system, any system belongs to one of two categories:

a- Open Loop system;

b- Closed Loop System.

Open loop systems are systems that include no feedback mechanism; while closed loop systems transmit the output again as an input to form a feedback loop. Inputs are processed by the systems transfer function T (S), to produce an output. Transfer functions are functions that transform inputs into another form of output.

Feedback loops are generally divided into two categories, *positive feedbacks* and *negative feedbacks*. Positive feedbacks are used by adding the output to the input at each time slot. Positive feedbacks are generally used to "generate growth, amplify deviations and reinforce change" (Sterman, 2000). Negative feedbacks, subtracts the output from the input in the next time slot. Negative feedbacks are usually used to simulate equilibrium, and are called "Goal Seeking" systems. Sterman (2000) identifies negative feedback loops as ".... loops that act to bring the state of the system in line with a goal or a desired state".

In the late 60s, the main language used to develop industrial dynamics simulation systems, was called 'Dynamo', a language that serves as the core simulation language for different simulation software used nowadays in industrial dynamics. Software packages such as, iThink, Stella and Vensim are used nowadays. The software that will be used in our simulations is "Vensim".

5.3 Relation between Industrial/ Business Dynamics and Evolutionary Economics: Establishing the Links

From Sections (5.1 and 5.2), it is clear that 'systems dynamics' as a simulation tool with shared properties that could be very useful when trying to simulate an evolving system. Such systems, and their dynamics, are time dependent and are the core paradigm that evolutionary economics preaches.

Feedback

One of those properties is 'feedback loops' (whether negative or positive). Feedback loops, and the notion of stocks, flows, rates and delays (as will be presented later) are simulation elements that are quite similar with the basics of an economy that evolves with time. Sterman (2000, page 385) strongly establishes the link between positive feedback, increasing returns and economic growth: he states that: "The recognition that positive feedback is the engine of economic growth can be traced back to Adam Smith's Wealth of Nations. Smith and the other classical economists did not draw causal diagrams, but the various feedbacks are clearly seen in their writings". Sterman (2000) explains that economists generally refer to positive feedback loops as "Increasing Returns". Sterman also refers to several economists beginning with Alfred Marshall (1890) and his theories of increasing returns, Krugman (1979) who established formal, positive feedback models describing international trade, and Romer (1990) who developed models of endogenous economic growth.

Swann (1998) indeed used the term 'Positive Feedback' when trying to explain the life cycles of industrial clusters. Swann (1998) asserted: "Firms in clusters grow faster than those in isolation, and that clusters attract a higher rate of entry at least during the early and growth phases of the life cycle for a particular industry. This happens because of agglomeration economies, which impact on entry and growth and hence lead to a form of *positive feedback*". Using a similar model, Beaudry (2001) found such a positive feedback loop in the entry of firms within aerospace clusters.

Systems that are dominated by positive feedbacks induce the creation of what is called "path dependence" (Sterman, 2000). Path dependence is "a pattern of behaviour in which the ultimate equilibrium depends on the initial conditions and random shocks as the system evolves. In a path-dependent system, small unpredictable events early in the history of the system can decisively determine its ultimate fate". The term "path dependence" is used by (Swann et *al.*, 1998) who assert that competition between clusters is heavily influenced by what could be considered 'minor historical events' (Swann et *al.*, 1998). It is said that the rise of Santa Carla Valley was basically due to the decision of a professor (later to be Vice-President) to work in Stanford University rather than another university located in the east coast.

Feedbacks as mentioned before, do not only serve as a simulation tool for growth or equilibrium, more importantly, they serve as *a learning mechanism.* Learning as a mechanism, is one of the main foundations of evolutionary economics, and is an aspect that Nelson and Winter used to build arguments against the foundation of classical economics. Learning is usually induced by feedback. Feedback induces learning, where it consists of a decision based on an output that changes the input of the system in the next time slot.

An example, consider a firm that newly enters the market. This firm first tries to adapt and learn about the market dynamics. Different strategies are used in different time slots, each with an outcome that contributes to the decision taken in the next time slot. The firm uses these strategies sequentially until it reaches the best strategy that makes it achieve its objectives or highest utility.

Stocks

The notion of 'stocks' (referred to by 'levels' in the simulation) indicates the level of the variable been studied, given the inflow and outflow of that system. An example of levels could be demonstrated by the level of innovation in a certain cluster (measured by the number of patents or products for example), and depend on the inflow of factors that both affect that level, in a positive or a negative way, and finally produces a flow that affects the overall economy similarly.

Rates

Rates are valves that control the rate of flow into stocks (that affects the level in that stock). Some factors control these rates that control the flow. An example of rates could be the rate of inventions that a certain firm produces in a certain period of time. Factors affecting the rates on inventions could be the amount of R&D spending in the same time slot.

Delays

There are three types of time delays that affect the flow in the system: First, Second, and Third Order delays. The second and third order delays are usually referred to, as the higher order delays. First order delay mixes material that enters in the stock at each time slot of entry. Therefore, first order delays are basically a single 'stock'. Higher order delays are usually designed by cascading (or putting in series) n first-order delays (or stocks). When treating delays, it is important to note that systems dynamics models are continuous in time. However, data are reported at discrete intervals (Sterman, 2000). While modelling delays it is important to note that, if delays represent material flow, the flow is conserved. Information feedback channels are not conserved. If we use a pulse signal, as an input to a first order delay the result is an exponentially decaying output, with the higher response after the pulse signal is initiated. In the case of higher-order delays, the output starts with a zero, reaches it maximum then the signal decays. In first order delays, stocks of material in transit are mixed all the time, as a consequence of this, the output is independent of the entry order (Sterman, 2000). The higher the order of the delays (putting more stocks in cascade) the less inputs are mixed and the lower the variance in the distribution of output.

An example of simple delay, imagine the delay between the patent application and the granting of that patent protection. Such a delay can be of a crucial importance to policy and firms' decision makers.

Systems representing an economy evolving with time are dynamic, and deal with linear as well as non-linear systems. It is important to note that economists often used linear systems for simplicity. However social complex systems are often non-linear in nature. Samuelson (1947) emphasized this by saying "Up until now economists have concerned themselves with linear systems, not because of any belief that the facts were so simple, but rather because of the mathematically simple and exact solutions are known. But a high price is paid for this simplicity in terms of special assumptions which must be made".

Obviously, the main role of simulation in economics is to understand the dynamics of systems that cannot be solved mathematically in order to make decisions. Industrial Dynamics is basically build for decision makers and managers, who deal with complex problems, and have to solve it without discarding any minor details.

Finally, in evolutionary economics, the notion of 'bounded rationality' is of a great importance. Several economists addressed the issue of bounded rationality and its effects on decision-making. Among those economists are Nelson and Winter (1982), and Simon (1957) where Simon states (Sterman, 2000, p. 598): "The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problem whose solution is required for objectively rational behaviour in the real world or even for a reasonable approximation to such objective rationality". Policy and decision makers are usually faced by complex problems that are finally translated to "complex stochastic, dynamic optimization problems" (Sterman, 2000).

In order to solve these problems, decision makers should be able to formulate the problem correctly by:

A- Addressing the correct variables (and that includes variables affecting their decisions in the future);

B- Formulate a working model that includes these variables;

C- Hold a cognitive capacity to solve the problematic at hand;

D- And the time to put all this into actions.

Given our bounded rationality, and our mental cognitive limitations as humans, optimal decisions could be very hard, and almost impossible in such problems, or even much more simple ones as Sterman (2000) asserts. The power of using industrial dynamics with its various tools such as, causal loop diagrams, flow diagrams, using its different components (as will be seen later) makes it much more easy for policy and decision makers, to formulate such stochastic problems, simulate and observe the outcomes of decisions.

5.4 Systems Dynamics Tools

5.4.1 Causal Loops

After identifying different variables, understanding how those variables affect each other is crucial to build a working model. This is identified in econometrics as "causal effects" between different variables. While econometrics tries to infer relationships between those variables using tests (Wooldridge, 2000), simulation induces assumptions and then simulates the dynamics of the system. In our case, simulations will be used as a hypothesis-testing tool.

The aim of building causal loop diagrams is to understand the relations between the variables in the model and their various effects.

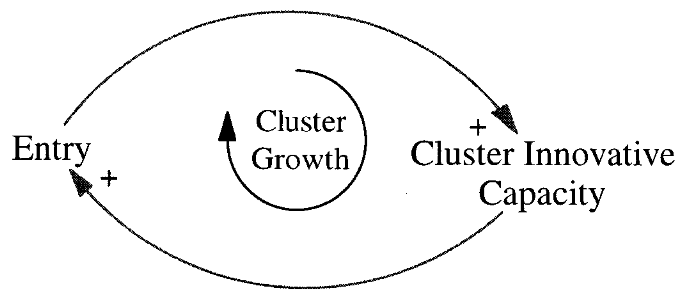

Figure 5.1 Cluster growth with positive feedback (Causal Loop)

Figure 5.1 explains that entry affects positively a cluster's innovative capacity. At the same time, as the cluster's innovative capacity increases, new entrants are attracted to the cluster. This of course is the design of a positive feedback system, increasing the entrants, and the cluster's innovative capacity with time. The arrow in the center denotes the identity of the positive feedback loop, which is cluster growth. Please note that a'+' sign on the arrow's head means positively affecting, while a '-' means negatively affecting.

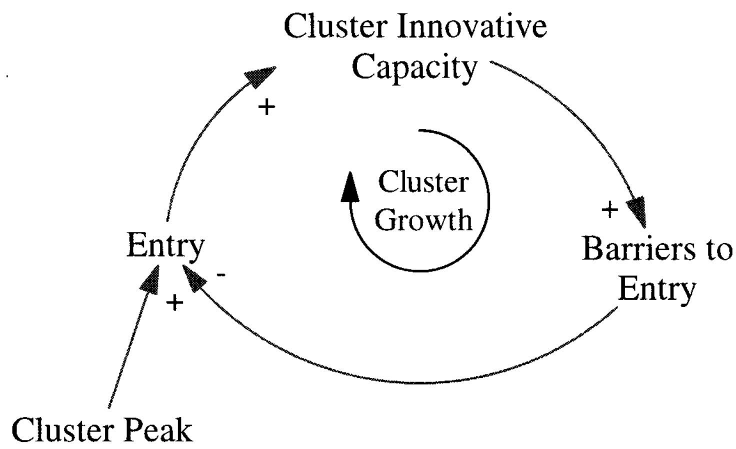

Figure 5.2 Cluster growth with negative feedback (Causal Loop)

Figure 5.2 explains that as more entrants enter a certain cluster, the cluster's innovative capacity increases, and the barriers to entry increase. Barriers to entry increase in such a case due to the highly differentiated products that incumbent firms produce, and this is what Bain (1956) labels "Product Differentiation Barrier to Entry". As the cluster gets crowded with time, and reaches its peak, entrants start to decrease due to congestion costs, and other factors affecting 'entry', such as increasing barriers to entry and congestion costs that increase with time. In that case, cluster growth will decrease over time, since the faster is the growth, the higher are the barriers and the fewer entrants there are. This loop is called a negative feedback loop, or a goal-seeking algorithm, since it is limited by the cluster peak value, which could be for example the maximum number of firms or aggregate employment at a certain point of time in the cluster.

5.4.2 Stocks, Flows and Rates

Now that causal loops are introduced, using positive or negative feedbacks, stocks and flows are presented in Figure 5.3.

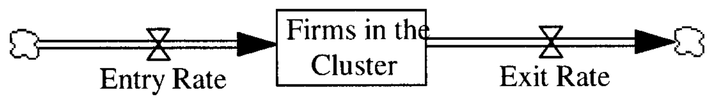

Figure 5.3 Level of firms in a cluster (Stock Flow)

The box called "Firms in the cluster" is a stock. Imagine a stock as a recipient that has water as an input and an exit. Both inputs and outputs, to and from the stock are controlled using valves. Those valves control the inputs and exit rates. Figure 5-3 explains that the level of firms in a certain cluster (which is the integral of the difference between inputs and outputs) is calculated by an entry rate (say the number of firms that enter a certain cluster in a certain time period) and the exit rate. (Which is the number of firms exiting a certain cluster at a certain time period). The level of firms in the cluster (or water in the stock) is calculated using Euler integration, at each time slot. Euler integration could be represented using the following equation:

$$S_{t+dt} = S_t + dt * (I_t - O_t) \quad (5.1)$$

In equation (5.1), the level in the stock at each time slot (t+dt) is represented by S_{t+dt}. S_{t+dt} is calculated by adding the level of the stock at the previous time slot denoted by S_t to the output (O_t) subtracted from the input (I_t), multiplied by the time slot in which we are measuring the phenomena being studied. Euler integration is essentially a numerical integration, and is widely used in simulation specially in simulating social systems. Since computer and digital systems basically use discrete time simulations, Euler is the method often used to run simulation models on computers.

It can be seen from equation (5.1) that the more the delta time we are using in the simulation is large, the larger is the error. But since the error in data from social systems is already large, such errors resulting from Euler are minimal and do not affect the simulation results significantly.

Integration starts from an initial value and is induced at the beginning of the simulation. For example the number of firms in the simulation can start by 1 firm (a monopoly), or a number of firms depending on the problematic being studied.

The rate of flow inside the system is adjusted using the valves. And this of course affects the level of 'liquid' or number of firms inside the cluster.

We will see in the next section how these flows, stocks and rates are calculated and what factors affect them.

5.5 The Model

5.5.1 Simulation Objective

The main objective of this simulation is to better understand the dynamics behind the formation of industrial clusters. This is established by simulating two runs. The first run will simulate entry, exit and cluster development with time. The second run will enable us to study the effect of an industry shakeout and its impact on the overall system. The second run is quite important to understand the dynamics of the telecommunication industry bubble boom and burst that took place in 2000-2001.

Industrial clusters develop with time, as more entrants are attracted to a specific location, stimulating entry. A literature review about entry, exit and survival was presented in chapter 1, so we will be brief here. Various models have been developed in the field of industrial organization and industrial clusters literature to explain entry mathematically. Such models include full entry and average entry models developed by Swann (1998).

In order to build the system, a general introduction for the model takes place in section 5.5.2, relations between those variables are established and implemented using the causal relationship between each one of them in section 5.5.3, and after that a stock flow diagram is built to simulate the system presented by causal loops in section 5.5.4. In section 5.5.5, simulation runs are presented and compared with the theory provided in chapter 1 and the literature.

5.5.2 Model Introduction

Variables in that model are extracted from Swann's (1998) analysis of clustering in high-technology industries. The main variables affecting clustering of firms in specific locations are basically: search costs, information externalities, technology spillovers, specialized labor, infrastructure benefits, and congestion costs.

Swann (1998) identifies clusters life cycles by the following three phases: first the rise, fall then the renaissance of clusters. First, clusters start by attracting new entrants, and firm growth is faster. Obviously this could be represented by a positive feedback simulating growth. After a certain time, the price of locating inside a cluster starts to rise. As the industry enters its maturity stage, the benefits of clustering start to decrease. As the cluster approaches its peak performance, industries inside the cluster according to Swann (1998) start to decline. At this point of time, industries start to decline, and only large mature firms survive. Certainly new entrants cease to enter such clusters searching for a better one that offers more benefits.

Klepper and Simons (2004) identified the various forms of industry shakeouts. They demonstrated that shakeouts occurred in highly concentrated markets. In their classification of different industry shakeouts featuring innovation, the resultant of each of the three scenarios (see chapter 1), is that the industry shakes-out until all unsuccessful innovators exit (radical invention theory and dominant design theory) or earliest entrants with the highest R&D manage to survive and other firms exit, even highly financed ones (competitive advantage theory).

5.5.3 Causal Loop Diagram

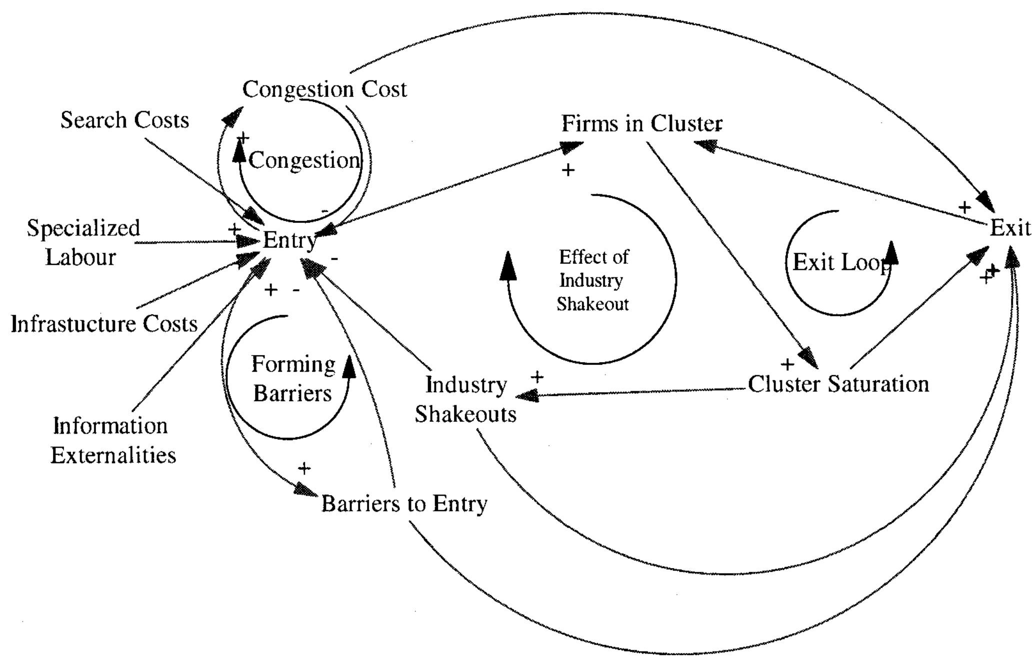

Figure 5.4 Entry and exit of firms in a certain cluster (Causal Loop)

In figure 5.4, the various causal relations in the system are connected. It could be seen that, the advantages to entry described by Swann (1998) are: search costs, specialized labor, infrastructure costs, information externalities all affect entry positively. This is illustrated by the positive signs on the arrows pointing at 'Entry'. The more the congestion costs increase the more 'Entry' decreases, and the more entry increases, the more congestion costs increase. This is noted by the loop 'Congestion'. As more entrants enter a certain cluster, barriers to entry increase, however, the more the barriers to entry increase, the more it affects negatively 'Entry'. This is marked by the loop 'Forming Barriers'. The more entrants rush into a certain cluster, the more it becomes congested, and at the same time the cluster approaches its peak (denoted by cluster saturation), and a shakeout is more likely to occur, leading to an increase in the exit rate, and a decrease in the entry rate. This is presented by the loop 'effect of industry shakeout'. This is a negative feedback loop, while the more the cluster matures the more likely that the rate of exit increases, and this is represented by the positive feedback loop called 'Firm Exit'.

5.5.4 Stocks, Flows and Rates

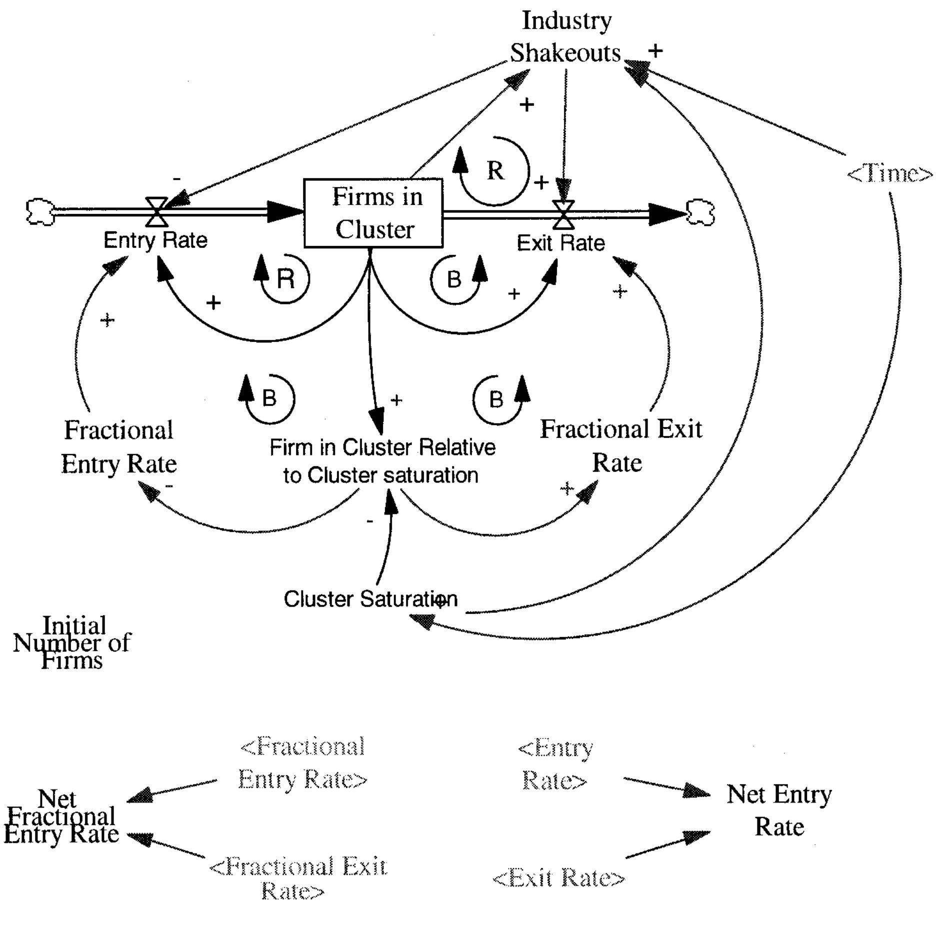

Figure 5.5 Flow diagram of cluster growth (Partly inspired from Sterman (2000))

The system described in figure 5.5 is inspired from the model presented by Sterman (2000) when explaining the growth of population. The above model will simulate a cluster growing with time until it reaches it maturity or peak. Then the simulation will include an industry shakeout on the overall system.

The system is described using the following equations (for equation details look at appendix to this chapter):

Cluster Saturation defines the maximum sustainable numbers of firms in a certain cluster. We put a predefined hypothesis; before the simulation to be 200 firms at the cluster growth phase, and then with the decline of the cluster, and after 10 years, the saturation is 100 firms.

$$\text{Cluster Saturation} = \begin{cases} 200, \text{ time} \leq 10 \\ 100, \text{ time} > 10 \end{cases} \quad (5.2)$$

In other words, the variable 'Cluster Saturation' holds the saturation point at which the cluster reaches its peak or saturates. The period in which the cluster reaches its saturation is not predefined, however it is assumed that after 10 years, (including some years of saturation), the cluster will start to decline if it is subject to a severe industry shakeout.

Entry Rate defines the number of firms that enter a certain industrial cluster yearly, and is calculated as the fractional entry rate of firms in the cluster. In other words, entry is proportional to the firms already in the market. In case there is an industry shakeout, the entry rate is affected by decreasing the rate of entry of a certain value, called industry shakeouts (see industry shakeouts for more details). The units of entry rate are the number of firms per year.

$$\text{Entry Rate} = \left|(\text{Fractional Entry Rate} * \text{Firms in Cluster} - \text{Industry Shakeouts})\right| \quad (5.3)$$

Equation (5.3) explains how entry rate at each time slot is calculated. It is calculated by taking the absolute value of the fractional entry rate of firms currently in the cluster. This value diminishes with the value of industry shakeout in case a shakeout occurs.

Exit Rate defines the number of firms that exit a certain industrial cluster yearly, and is calculated as the fractional exit rate of firms in the cluster. In case industry shakeouts occur, the exit rate is affected by increasing its value by a number called 'industry shakeouts'. (See industry shakeouts for more details). The unit of exit rate is the number of firms per year.

$$\text{Exit Rate} = \text{Fractional Exit Rate} * \text{Firms in Cluster} + \text{Industry Shakeouts} \quad (5.4)$$

Equation (5.4) shows how firm exit rate is calculated. It is calculated as the fractional exit rate of firms in the cluster. If an industry shakeout occurs, its value is added to the exit rate, simulating a dynamic increase in the exit rate.

Final time represents the total time for the simulation, and in the current simulation, we have chosen a period of 15 years to simulate.

Firm in Cluster Relative to Cluster saturation is the ratio of firms in the cluster with respect to cluster saturation points. Of course the ratio is dimensionless. The ratio of 'firms in the cluster' to 'cluster saturation'. This ratio is used to determine the fractional entry and exit rates.

$$\text{Firm in cluster relative to cluster saturation} = \frac{\text{Firms in the cluster}}{\text{Cluster Saturation}} \quad (5.5)$$[14]

Equation (5.5) shows that the more firms enter in the cluster, the more the cluster gets saturated, or approaches its peak. The value of 'firm in cluster relative to cluster saturation' is '1' indicating that the cluster is currently saturated. At each time step of the simulation, cluster gets more and more saturated.

[14] Inspired from Sterman (2000) however calibrated to suit our case

Firms in Cluster denotes the integral of the difference between entry rate and exit rate. In other words, firms in the cluster are increased by entry rates and decreased by exit rates. The initial level of firms in that cluster is initiated by the value 'initial number of firms' that holds the value of 1, assuming a monopoly position. The number of firms in the cluster is calculated at each time slot.

$$\text{Firms in Cluster} = \int_{\text{Initial Number of Firms}} \text{Entry Rate - Exit Rate} \quad (5.6)$$ [15]

Equation (5.6) is an Euler integration that holds the value of 'initial number of firms' in the cluster as an initial value. 'Firms in Cluster' is a stock or level value that integrates the value of entry rate less the exit rate at each time step, simulating the level of the number of firms in the cluster.

Fractional Entry Rate represents the declining function of the 'firms in the cluster' relative to the maximum number of firms or employment a certain cluster can hold. A logistic function is used and calibrated[16] to fit our needs. Unit here is 1/Year.

$$\text{Fractional Entry Rate} = 1 - \left(\frac{1}{1 + e^{(-\beta * \text{Firm in Cluster Relative to Cluster saturation} - 1)}}\right) \quad (5.7)$$ [17]

The more the cluster gets saturated, the less the fractional entry rate is. This is represented by the logistic function in equation (5.7). The value of β is calibrated in the simulation. The results shown for the simulation (In the next section) will hold a value of β equal 7.

Fractional Exit Rate is an increasing function of the ratio of 'Firms in cluster' to 'cluster saturation'. A power function is assumed. Unit of that variable is 1/Year.

$$\text{Fractional Exit Rate} = \alpha + \alpha * (\text{Firm in Cluster Relative to Cluster saturation})^3 \quad (5.8)$$ [18]

Fractional exit rate is calculated in the simulation using equation 5.8. Exit rates starts with the value of α at the simulation start time. The more the cluster gets filled with

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[15] Inspired from Sterman (2000) however calibrated to suit our case

[16] The model parameters calibration is done by using trial and error in order to obtain the graphs that explain the theoretical literature.

[17] Sterman (2000); Calibrated to suit our case

[18] Sterman (2000) and Used by Swann (1998); Calibrated to suit our case

firms, the more the fractional exit rate increases. In the simulation at hand, we assumed a value for α equal to 0.2, meaning that at the first time step of the simulation, 2 out of 10 firms will exit the cluster; this value will increase the more the cluster gets saturated, or reaches its peak. It worth to note that such polynomial functions are used by Swann (2000).

Industry Shakeouts represents the sudden change in the industry, presented as a change in the rate of entry and exit inside the cluster. The industry shakeout occurs when firms in the cluster exceeds the value of cluster saturation. The value of the change in that rate is represented by a '–ve' exponential function that is diminishing with time. This has the role of decreasing the value of the impact with time, since firms start to adapt, and different strategies are used to minimize exits and maximize entry.

$$\text{Industry Shakeouts} = \begin{cases} \gamma * e^{-\text{Time}}, & \text{Firms in Cluster} \geq \text{Cluster Saturation} \\ 0, & \text{Firms in Cluster} < \text{Cluster Saturation} \end{cases} \tag{5.9}$$

Equation (5.9) describes the occurrence of an industry shakeout. This shakeout is triggered when firms in the cluster reach the cluster saturation level. The value of that shakeout has as a value $e^{-\text{Time}}$, which is an exponential function decaying with the increase in time. In other words, after this shakeout occurs, its magnitude diminishes with time. We can see the simulated shakeouts in figure (5.6)

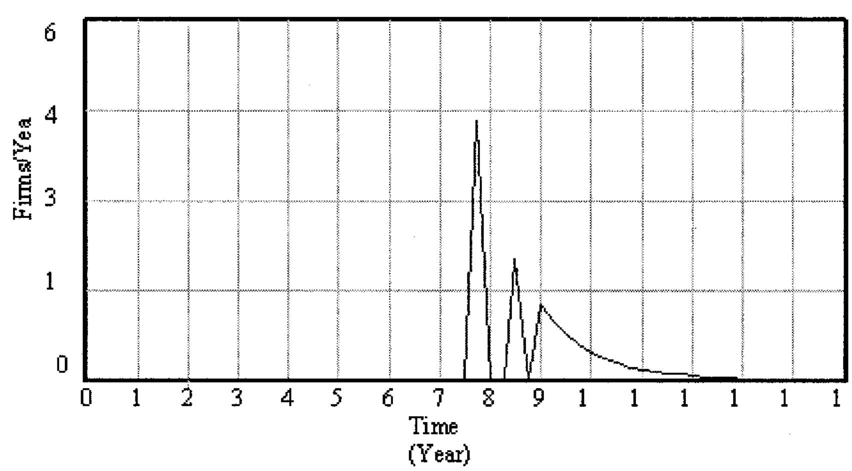

Figure 5.6 Industry Shakeout Graph

<u>*Net Entry Rate*</u> is calculated by subtracting exit rates from entry rates at each time slot and demonstrated by equation (5.10). The unit of 'net entry rate' is Number of Firms/Year

Net Entry Rate= Entry Rate-Exit Rate (5.10)[19]

<u>*Net Fractional Entry Rate*</u> is calculated by performing the operation, fractional entry rate less fractional exit rate. And the units used are 1/Year.

Net Fractional Entry Rate= Fractional Entry Rate-Fractional Exit Rate (5.11) [20]

5.5.5 Simulation

The simulation starts with one firm in the market, with a simulation time span that lasts 15 years. As mentioned before, there are two proposed scenarios. The first scenario shows a cluster that reaches its peak and becomes concentrated, with no shakeout. The second scenario simulates a cluster that reaches its maturity peak, and then an industry shakeout occurs.

<u>***Scenario 1 (without shakeout)***</u>

As we can see in figure 5.7, and figure 5.8 entry and Exit rates are presented. First, firms enter the cluster; the entry rate reaches its peak when the number of firms in the cluster reaches the cluster saturation point, which is 200 firms in our model (See figure 5-9).

[19] Inspired from Sterman (2000); Calibrated to suit our case
[20] Inspired from Sterman (2000); Calibrated to suit our case

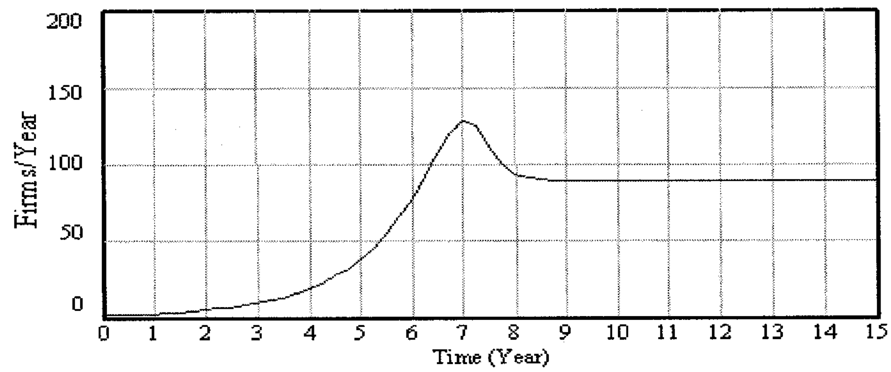

Figure 5.7 Entry Rate (No Industry Shakeout)

As the cluster reaches its saturation point, entry rates decline till it reaches a constant level, based on which the system stabilizes. In our case, when the cluster saturates, entry rate becomes constant at a 100 firm per year. As the number of entry increases, and the cluster becomes more saturated with time, firms exit rate increases (see figure 5.8). Since entry rate and exit rate becomes equal after cluster saturation, the cluster remains with the same number of firm afterwards (see figure 5.9).

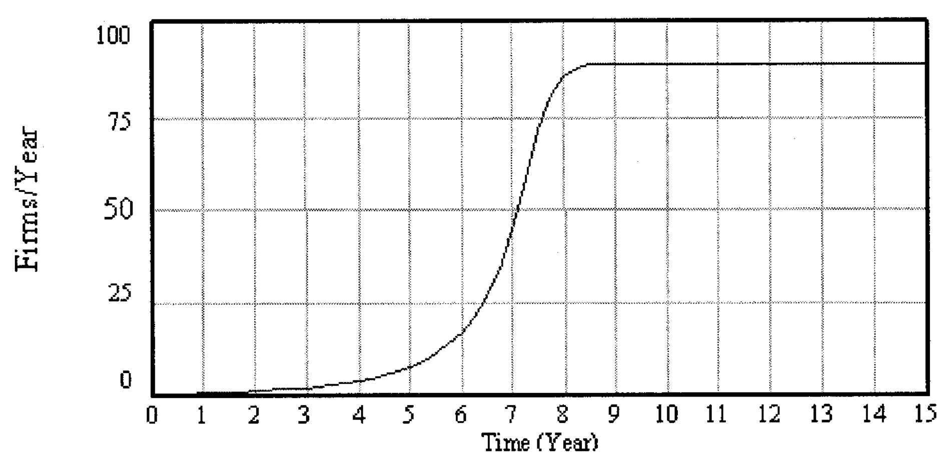

Figure 5.8 Exit Rate (No Industry Shakeout)

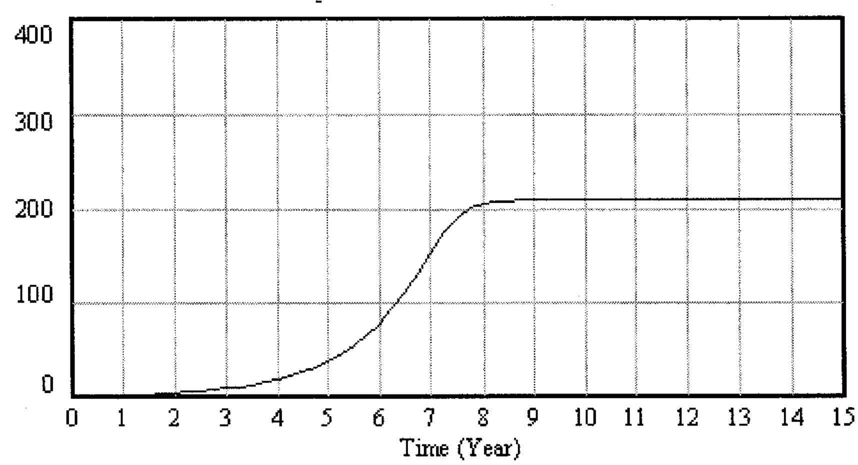

Figure 5.9 Number of Firms in Cluster (No Industry Shakeout)

As seen, the simulation starts with one firm entering a certain cluster. As more entrants see benefits of entering the cluster, and almost no disadvantages, firms rush in, with a high entry rate. It could be also seen that the exit rates are quite low while entry rates are high in the first time block. While more firms enter the cluster, congestion costs arise, and the number of firms in the cluster (could be measured by employment too) reaches it peak, or its maturity phase. After the cluster reaches its maturity phase, entry rate decreases, and exit rates reach their peak and stabilizes there. This is what Swann (1998) labeled the first stage, or the rise of a cluster.

We can relate this to the following: in the beginning of the creation of a cluster, entry barriers are very small, and benefits outweighs the congestion disadvantages of the cluster, this allowed that all firms that attempt to enter the cluster will succeed, however this ratio diminishes with time, as the cluster gets more mature, competition rises, profit margins fall, and congestion costs increase, leading to a severe drop in the fractional entry rate. Of course the opposite occurs with the exit rate, where exits become more frequent the more the cluster gets into its maturity and decline phase.

Scenario 2 (with shakeout)

In that scenario, we will simulate the occurrence of an industry shakeout. The shakeout demonstrated in figure 5.6 will be applied to entry and exit rates of the system. In figure 5.10 we can see that exit began with a slow rate as the cluster began to form still beneficial for clustering. In the meantime we can see in figure 5.11 that entry rate is increasing with a higher acceleration.

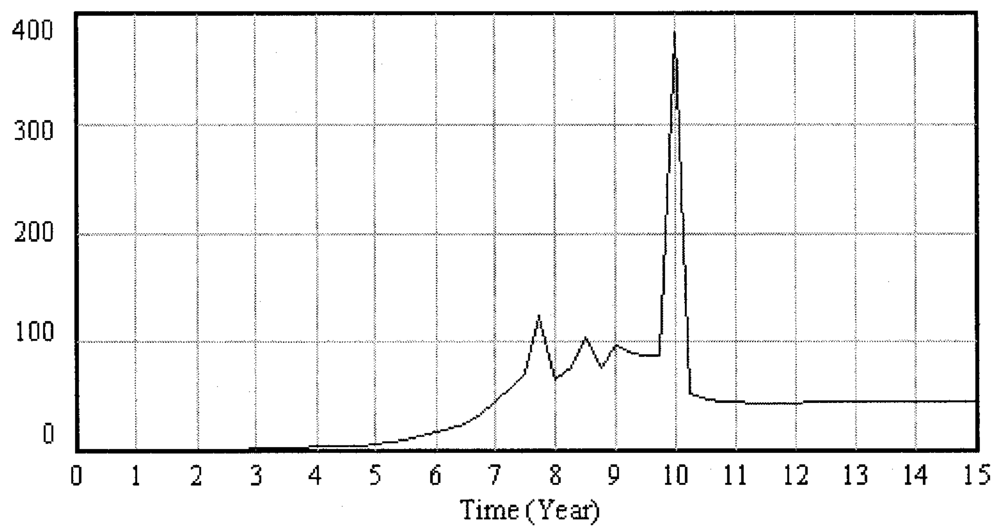

Figure 5.10 Exit Rate (With Industry Shakeouts)

After a certain period of time (3 years in our case), and as the cluster begins to saturate the cluster suffers from an industry shakeouts. This industry shakeouts increased exit rates dramatically, and decreased in the same time entry rates. While exit rates are at their peak (year 10 of the simulation), entry is equal to ZERO (see figure 5.11).

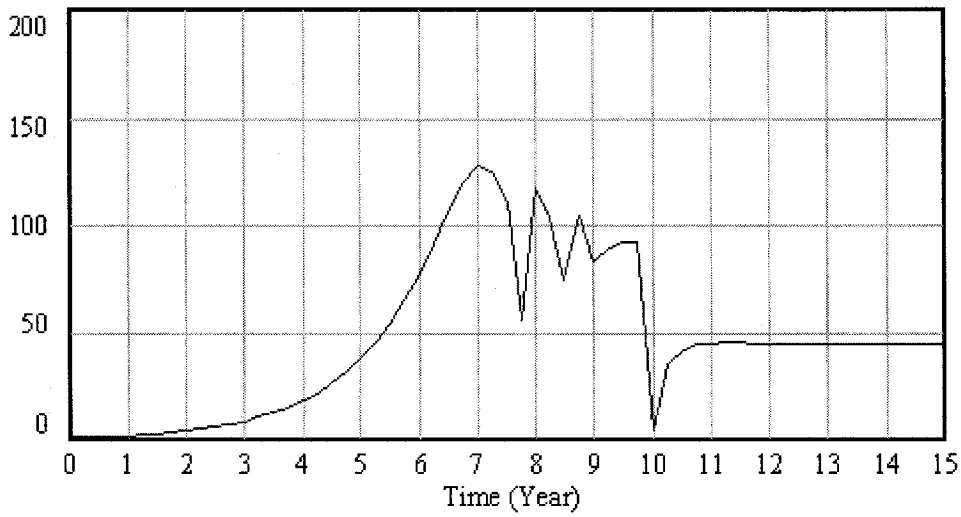

Figure 5.11 Entry Rate (With Industry Shakeouts)

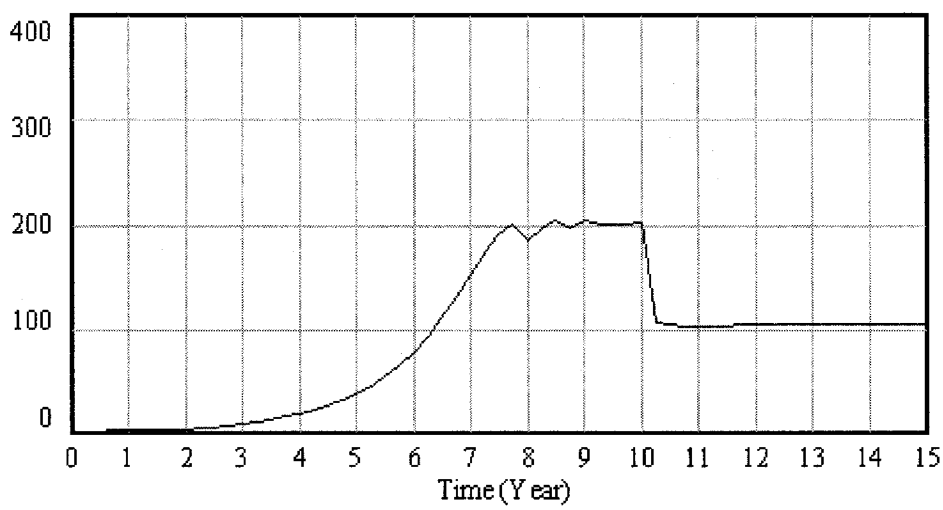

Figure 5.12 Firms in the Cluster (With Industry Shakeouts)

Figure 5-12 presents the level of firms in the cluster, from its birth, and growth (until year 8), its saturation and oscillation around 200 firms, then its decline at year 10 due to the industry shakeout. After the overall system shakes, it stabilizes around a 100 firms in the cluster. Those firms are the firms that were capable to survive the shakeout.

Now we can understand the clustering dynamics as follows: After the cluster birth, and reaching its peak, and the cluster becomes more concentrated, a shakeout occurs, entry rates hence decrease heavily, while at the same time, exit rates reach their peak. This is what Klepper *et al.* (2004) referred to as the main three theories of industrial shakeouts. At first, in the *Radical Invention Theory*, a new invention builds an industry, in a certain cluster. Firms that can produce such invention or any other invention that complements it, rush in. As profits erode, unsuccessful innovators exit the market. Now a second phase occurs, identified by Utterback *et al.* (1993) as the *Dominant Design Theory*, where companies desiring to enter the market use process innovation, to produce the same product with a lower cost. Entry rates diminish with time, and a shakeout occurs, leading to a sever increase in the exit rates.

After the shakeout occurs, only early entrants with highly capable R&D spending policies manage to survive. This is what Klepper (2002) called the *Competitive Advantage Theory*. This could be easily witnessed, by the decrease in the stabilized number of firms in the cluster, from 200 firms to 100 firms.

5.6 Conclusion

In this chapter, we started by introducing simulation, as a tool, to understand social complex systems. After that we shed some light on the works of other researchers who used simulation to understand the dynamics of markets, in different industries. Then we introduced the basics of industrial dynamics, a tool used for simulation using control systems methodology. After introducing industrial dynamics, we have shown the similarities, between different aspects of industrial dynamics and evolutionary economics, and why industrial dynamics as a tool is a very useful tool when trying to study evolving systems that develops with time. Tools used in industrial dynamics and its basic methodologies are then introduced to provide the reader with a basic understanding of the methodology used throughout the chapter.

The model, inspired from Sterman (2000) in his study to population, has been built using the basic theories in industrial clusters and industrial organization, mainly about entry, exit and industrial shakeouts. The work has been developed first using causal loop diagrams then a stock flow diagram was developed to simulate the flow inside the system. After developing the system, the simulation is run two times, one to demonstrate the rise of the cluster, and the second to demonstrate the fall and renaissance of the cluster, by applying an industry shakeout on the overall system.

Finally, the model presented is a very simple model that opens the door for future researchers to calibrate it according to the problematic being studied then test different policies accordingly.

CHAPTER 6 - CONCLUSION AND FUTURE WORK

6.1 Conclusion

The prime aim of this work is to understand the dynamics of the Canadian telecommunication equipment manufacturers' clusters. In order to understand these dynamics we have first identified the various school of thoughts that will enable us solve the problematic at hand; mainly evolutionary economics, theories of innovation and industrial organization literature concerning entry, exit and market concentration. It has been noticed that while Canadian researchers focused their efforts on various high technology industries like the biotechnology industry, the information and communication technology (ICT) and other manufacturing industry; none of them tackled the Canadian telecommunication equipment industry specifically.

One of the prime motivator that stimulates the dynamics in high technology clusters are technologies themselves. Therefore, a thorough research was established in order to identify the current technological trends in the telecommunication sector. Part of understanding the basics of the telecommunication industry, is the study of its historical evolution, therefore we have historically traced innovation in communication equipment from its early years in the 17^{th} century and the invention of the telegraph and its deployment into communication, passing by the telephone invention at the beginning of the 20^{th} century, until the current technological trends. We have seen that in general the industry started with breakthrough innovations (Such as that of Marconi, Bell and Morse) until the industry became extremely complex due to the first boom of the transistor in the 50s till the boom of data communication in the early eighties.

Together with the high technological advances that this sector is witnessing, we have shed some light on the role of the telecommunication industry deregulation, and its impact on entry of rival firms competing against incumbent ones like Bell and AT&T. To summarize we have identified four basic booming technological trends in the telecommunication industry namely; wireless, broadband, fiber and Voice over IP technologies.

Now that the theoretical and technological backgrounds were investigated, we have started collecting our data to perform our analysis. A longitudinal database, on the firm level was constructed. The database was built by merging various databases. This database mainly enabled us to identify and locate geographically the various telecommunication equipment industrial clusters all over Canada, together with their aggregate firms' sales (as a measure of cluster performance) and employment to study the evolution of firms' size inside each of the identified clusters.

We have found that Canadian Telecommunication Equipment firms clustered mainly in big cities, namely; Ottawa, Montreal, Toronto, Calgary and Vancouver. The effect of the IBBB was quite visible. Toronto cluster seems to have suffered the most driven by the rapid deterioration of Nortel stocks and the apparent collapse of the industry. While Brampton specifically suffered huge losses, we remarked a recent increase in sales in the Waterloo region, driven by the firm 'Research in Motion' that mainly manufactures wireless technologies for end users. Sales did not only drop in the Toronto region, they also dropped in Vancouver, Montreal and Ottawa.

It was also noticed that; while bigger financial cities, such as Toronto, Montreal and Vancouver were directly affected by the industry shakeout of the IBBB, some kind of a delayed response took place in Ottawa. While most of the telecommunication-manufacturing firms, had their headquarters in Toronto, Montreal, and Vancouver (aiming to cluster beside their financial institutions, and benefit from infrastructure benefits such as airports to reach their international customers and else), Ottawa seems to be the place for smaller, innovative firms. This argument could be supported by the fact that even Nortel innovative output sources from its main R&D office in Ottawa. And while the telecommunication industry is an international industry in nature, and that its demand goes beyond local demand to cover international markets, firms headquarters located in Canadian financial cities where the ones primarily and spontaneously affected. In the mean time and after suffering greatly, firms located in Ottawa began to suffer. Therefore our main finding is that in general, Ottawa, together with Saint-Laurent and Burnaby are the main sources of R&D activities in the telecommunication industry and that they supply their innovative products to their headquarters to be marketed and sold (Domestically and Internationally). Since the IBBB crisis basically originated from the international markets, sustained by a temporary drop on the local demand side, firms in Ottawa got affected in a some what delayed manner.

With respect to firms' size, we have found, that Montreal and Toronto clusters generally held a homogenous diversification in terms of firms sizes, and that the crisis, almost affected each and every category. This was not true in Ottawa, where for example the main reduction in firms' sizes was mainly focused on the 5 to 9 employees' category. Generally, we have found that smaller firms are the ones that mainly suffered the downturn of the IBBB, with a different magnitude among different clusters, with less harm done to the biggest firms. This finding is quite evident subsequent to the IBBB; however when we studied the overall sample from Cancorp financials, we discovered that in general older firms usually were the ones exiting the telecommunication market. We explained this finding by the following: while the industry of the telecom started to mature in the 80s, older firms unable to adapt died, while newly born firms had the competitive advantage to survive with their newly innovative ideas, however when submitted to the industry shakeout, newer firms died, while older ones survived.

From here we have drawn an interesting conclusion; with a technology shift sustained by a general economic growth, innovative ideas could guarantee growth on the firms' level. In case of industry shakeouts, firms with more financial capabilities survive, while more innovative, smaller firms could be subject to more death in their own clusters. Please note that the majority of firms in the telecommunication industry are publicly traded firms, hence, supported by intense capitals and complicated financial structures that enables them: *first,* to survive economic and technological downturns, *second*, to acquire newly born firms that constitute a technological threat and offer substitutes for the technology they provide, or offers a complementary product that enables them to diversify their product portfolio to address different clients segments.

Now that we have identified clusters and their general performance, we have investigated the technological identify of those clusters; using their main firms' age together with their main technological activities and innovative output (using patents). In order to carry this investigation we have used our longitudinal database on the firm level to investigate technological activities, as well as firms' age, and we constructed a database that described innovative output on the regional levels using the data gathered from the Canadian Intellectual and property office (CIPO).

From our analysis, we have found that the Canadian Telecommunication Equipment Industry is a highly protected industry. The several incumbent firms enjoy a protection from entry, building 'Barriers to Entry' and offering aggressive protection to early entrants and capital-intensive R&D firms like Nortel, JDS Uniphase and Ericsson Canada.

On the technology side, we can notice that the degree of technology specialization is different among different clusters. This could be witnessed on both, firms' activities and patenting activities, in the various clusters studied.

We have found that the Ottawa cluster takes the lead producing all sorts of telecommunication technologies hence protecting itself, by increasing the cluster's technologically barriers to entry. It was remarkably noticed that, Ottawa cluster exceeds by far other clusters in the production of fiber technologies, probably driven by incumbent firms like Nortel and JDS Uniphase. On the broadband and wireless technology side, firms' activities seem to be active in different regions namely: Toronto, Vancouver, Ottawa, Montreal and Calgary. Of course this is mainly driven by the increasing demand from end users for wireless, and media communication. It is also remarkable that the Voice over IP (VoIP) as new emerging technology is still gaining ground; however, we cannot determine yet any kind of relation between technology and location. Waterloo is also an active firm with respect to wireless technology; this is mainly driven by the firm Research in Motion that patents in both wireless technology (its core competency) and lately in fiber technology, probably aiming at diversifying its product portfolio.

Big clusters such as Vancouver, Montreal, Toronto, Ottawa and Calgary contribute to patenting in the services side, and this is driven mainly by demand from operators scattered geographically in each region. With time, patenting activities with respect to telecommunication software management seems to be remarkably accelerating, driven mainly by the Ottawa region.

The current technology convergence, is now putting more pressure on the software layer to control network traffic, and put more security on networks. Also we have seen that voice technology is currently witnessing a remarkable advance, due to the emergence of the VoIP technology. The same phenomenon was witnessed in the wireless technology that became almost mandatory as a mean for telecommunication.

Generally, while big financial cities, Toronto and Montreal hold the majority of headquarters for manufacturing firms, innovative output is concentrated primarily in Ottawa (Kanata and Nepean) followed by Montreal (Saint-Laurent), Toronto and Vancouver.

On the firm level, early incumbent firms with highly intensive R&D finances hold the upper hand with respect to patenting activities. It was found that, in that industry firms' age played a key role in firms' survival. It is worthy to mention that Niosi (2000) classified the communication equipment industry as an old Oligopoly dating a hundred years ago, together with industries that hold similar structures such as the aircraft industry (80 years), drugs and medicines industry (120 years). Such industries hold less dispersed industry structures then younger industries such as the Biotechnology and the software industry.

Early entrants that managed to survive and adapt to the various economic and technological downturns, have with time, increased barriers to entry, keeping the door open only for very few firms, that have breakthrough or radical innovations, otherwise, those firms exit and are not able to survive. An example of this is firms like Nortel that have already invested in highly intensive R&D projects to increase barriers.

Those findings about the extensive R&D nature of the telecommunication is also supported with other researchers like Godoe (2000) and Rao (1999) who found that the telecommunication total R&D intensity increased where for example the communication equipment industry (SIC 366) R&D spending has doubled from 5.1% to 10.3%. Rao (1999) explained this dramatic increase in R&D intensity by the high increasing demand on new products and services in the telecommunication sector, which are subject to heavy R&D expenditures.

When examining Universities and their contribution to the innovative product, unlike other high technology clusters like the biotechnology, universities contribute minimally to telecommunication equipment clusters. Of course this does not deny the fact that Universities are a contributor to clusters innovative performance; however this is done indirectly through collaboration with incumbent telecommunication manufacturing firms. We have referred this to the high R&D structure that this industry holds, primarily controlled by incumbent firms.

In light of the hypothesis presented in Chapter 1 we can finally infer the following:

On the industry analysis side, we have seen that among the 5 identified clusters Toronto has financially suffered the most in 2000-2001, and that the impact has been delayed in Ottawa, a cluster that is characterized by a high technological diversity and innovative output. Montreal is definitely the older cluster among others, initiated by the early entrant of Western Electric (in 1915), and followed by Toronto cluster that started to grow after Northern Telecom locating there in 1977. After a while, Ottawa cluster started to grow, encouraging younger innovative firms to locate there to benefit from knowledge externalities. While Ottawa mainly held an innovative nature, Toronto was characterized as a cluster holding the majority of sales, marketing and financial activities in the CTEMs. Montreal and Toronto as the older clusters, held a homogeneous mix of establishments sizes indicating a stage of maturity.

In the 1980s older firms unable to adapt to the new technology shift in data communication died, while younger firms with highly innovative capacity survived. Subsequent to the IBBB, Montreal and Toronto witnessed a drop in the number of establishments across all sizes, while Ottawa was affected mainly in the 5-9 category; a category that characterizes entrepreneurial innovative firms in Ottawa. The IBBB shakeout in 2000-2001 held an economic international nature, and this probably explains why financial cities were more and first affected, followed by innovative ones. When submitted to IBBB (industry shakeout), newer firms died while older ones, with more adequate financial structure managed to survive

While Ottawa, Toronto and Montreal where probably driven by international demand, smaller clusters like Calgary and Vancouver were probably driven by local demands triggered by telecommunication operators expansions initiated by the increased demand on telecommunication services.

When examining the industry structure and the dynamics associated we have noticed that horizontal mergers were the main dynamics that influenced firms in the Telecommunications sector (Acquiring competition). These horizontal mergers mainly took place in Ottawa, the cluster seemingly the most dynamics. In Ottawa we also have seen spin-offs and entrepreneurs establishing new firms that have grown to the size of large enterprises, based on new innovative ideas

While Beckstead & Brown (2005), did not find any evidence of any structural shift in the ICT sector subsequent to the IBBB, in the CTEM sub sector of the ICT the dynamics are quite clear all over the different clusters, but with different magnitude according to clusters maturity phase. Where for example we noticed that Ottawa dynamics were mainly focused in the 5 to 9 employees category, while in elder less dynamic clusters like Montreal, and Toronto the changes affected almost all categories probably due to the structure of the supply chain governing their structure.

On the technology analysis side, and among the 4 identified technologies within the telecommunication, from firms' activities and patenting sides, we have noticed that Ottawa holds a diversified portfolio of technologies produced, thus increasing barriers to entry and fostering cluster competitiveness. While the Ottawa cluster seems to be a monopoly in the fiber technologies, broadband and wireless technologies are distributed among all clusters due to the high demand of wireless and broadband communication services. In the meantime we remarked that VoIP is still gaining ground, as a new technology, therefore we could not identify yet any kind of technological trend that is bound to location. Waterloo cannot be identified as a cluster; however as a region it is active in the wireless technology domain due to the firm Research in Motion.

This diversification in technologies and cross sub-sectoral activities within the Ottawa cluster is probably the main driver of its innovative performance, and that this cross sectoral effects promoted entry in Ottawa similar to what happened in the US computing industry (supporting Swann and Prevezer, 1996). This diversity among economic activities seems to have fostered the Ottawa cluster, more than specialized clusters like Montreal in the wireless domain (supporting Feldman and Audretsch, 1999), and that technologies themselves were a prime reason why Ottawa Cluster grew rapidly. In the same vein, this diversity across complementary industries and technologies, in Ottawa, within the telecommunication sector specifically and in the ICT generally generated greater returns on R&D supporting Jafee et al. (1993). Another reason of the rise of Ottawa (Identified as Silicon Valley North) is that as seen in the US computing industry, cross sectoral effects promoted entry. The Telecommunication industry is similar to the computing industry in that respect where it included different but interdependent sub-industries, which generates +ve feedback on all sectors (Broadband, Wirelss, Fiber and others). This cross sub-sectoral effects is also due to the nature of the OSI reference model that govern data communications. All the above evidence support Feldman and Audretsch (1999) studies for the US Computing industry.

On the universities side, and through patenting we found that university role is indirect, and is manifested through collaboration with the industry, supporting the main finding of Rosenberg et al. (1994) that emphasizes, that in general, university efforts are mainly directed towards long term problem solving, while industry focus on short term R&D (Rosenberg et al., 1994). This finding actually is similar to what Niosi and Zhegu (2002) found, due to the resemblance of industry structure of the Canadian Aerospace and the Telecommunication industry, where in both industries large firms dominate. Demand in both industries also is of international nature and in both the role of local demand and local inter firm competition is probably marginal. (Supporting Niosi and Zhegu, 2002).

This resemblance between the Aerospace and the Telecommunication sectors are also caused by the age of these industries, where both almost started a decade ago. Therefore, early entrants had lower hazards in any technological or economic shakeouts due to the great number of innovations of these firms. Where for example we saw from patenting analysis, that the Canadian Telecommunication Equipment industry is a highly protected industry where incumbent firms, holding an intensive R&D structure, like Nortel managed to increase technological and financial barriers to entry. In the meantime, innovative companies in these industries enjoyed a 'Rich get Richer' dynamics where this privileged incumbent position made other smaller entrants and innovators with less ability to cease from entering the market (supporting Klepper and Simons, 2004).

After we have explored the Canadian telecommunication industry dynamics, we have introduced industrial dynamics as a tool to simulate entry, exit, and the cluster life cycle. Using such a methodology, to our knowledge, is the first in the field of the industrial clusters domain. Throughout our investigation, we have shed some light on the works of other researchers who used simulation to understand the dynamics of markets, in different industries. Then we introduced the basics of industrial dynamics, a tool used for simulation using control systems methodology.

After introducing industrial dynamics, we have drawn a parallel, between different aspects of industrial dynamics and evolutionary economics, and why industrial dynamics as a tool is a very useful tool when trying to study evolving systems that develops with time. We build a model inspired from Sterman (2000), when studying population evolution. The model has been build using the basic theories in industrial clusters and industrial organization, mainly about entry, exit and industrial shakeouts, coupled with its perfect similarity with the evolution of population. The work has been developed first using causal loop diagrams, then a stock flow diagram was developed to simulate the flow inside the system. After developing the system, the simulation is run two times, one to demonstrate the rise of the cluster, and the second to demonstrate the fall and renaissance of the cluster, by applying an industry shakeout on the overall system.

6.2 Future research work

While this research mainly targeted manufacturers, future research could address the telecommunication services sector. Further research could target telecommunication service providers like Bell, Sprint as well as the various Internet service providers (ISP) and application service providers (ASP) across Canada.

Also more economic factors provided mainly by Industry Canada and Statistics Canada could be used in order to highlight the various economic factors affecting clustering in each of the identified clusters. Furthermore, and on the methodology side, econometric models, using panel data could be used in order to investigate the clustering phenomenon more thoroughly.

On the simulation side, we have investigated the field of industrial dynamics; more sophisticated models could be used using the same methodology in order to apply various spectrums of scenarios. While Business/Industrial dynamics tools, stands as a reliable methodology if we want to study the clustering phenomenon on the aggregate level, however on the firm level, this methodology could get more complicated if we use it on the firm level, therefore we propose to use agent based simulations in order to simulate a system, with more focus on internal firms' routines.

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ANNEX A: SALES IN DIFFERENT CLUSTERS

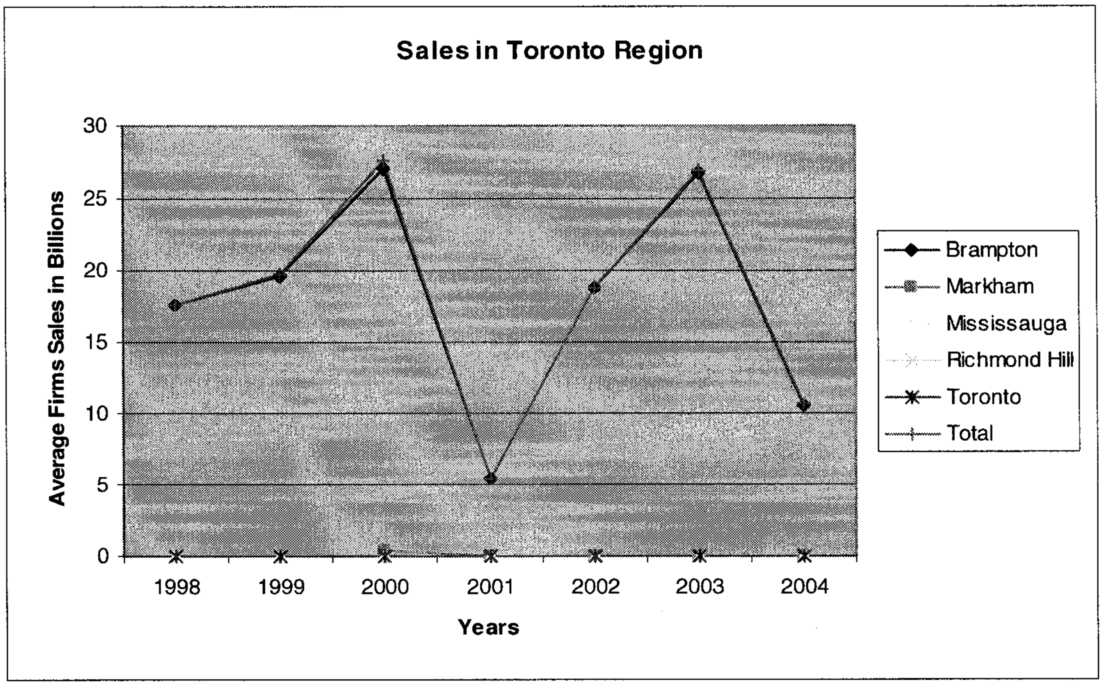


Figure A.1 Sales in Toronto Cluster

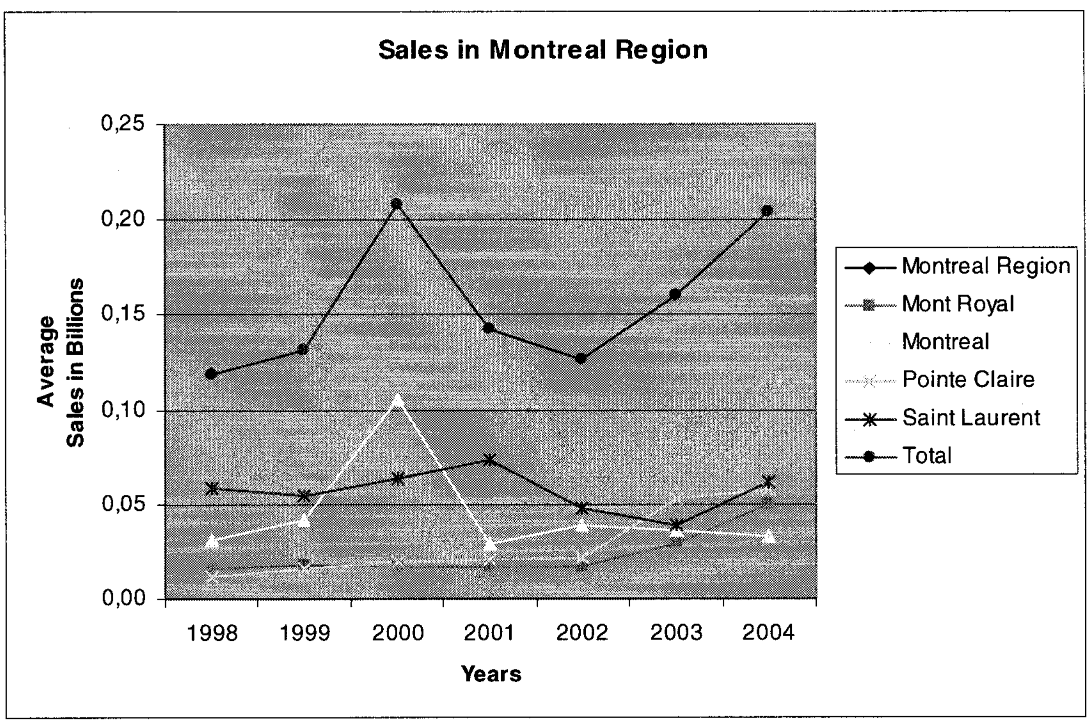


Figure A.2 Sales in Montreal Cluster

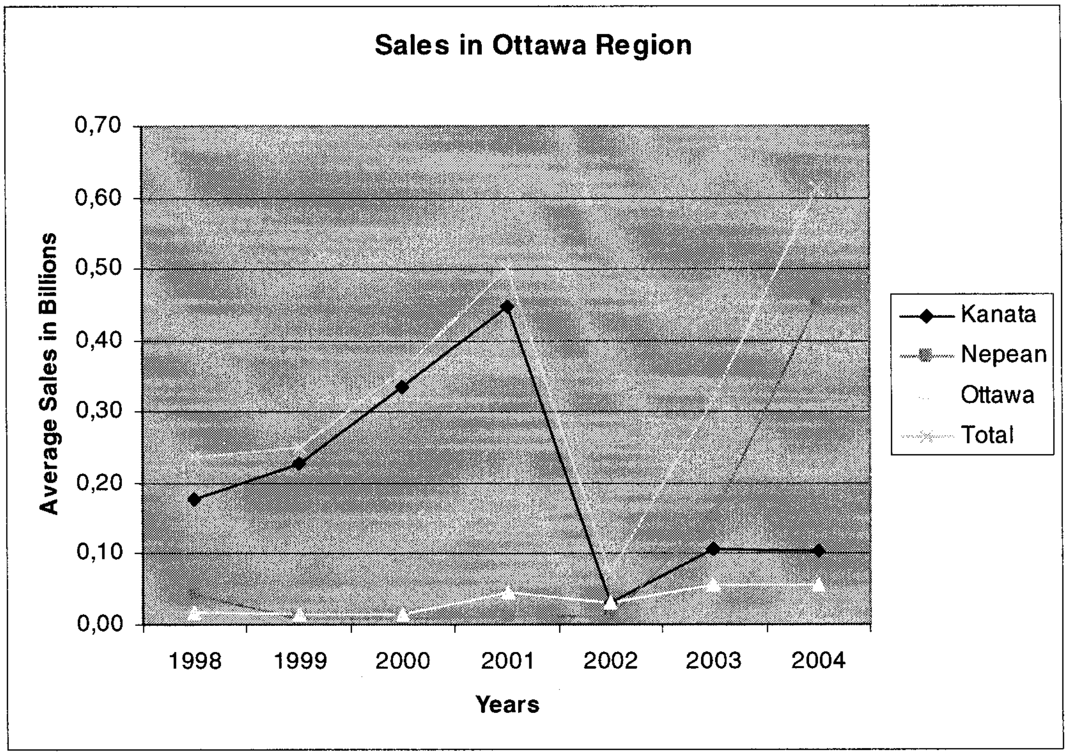


Figure A.3 Sales in Ottawa Cluster

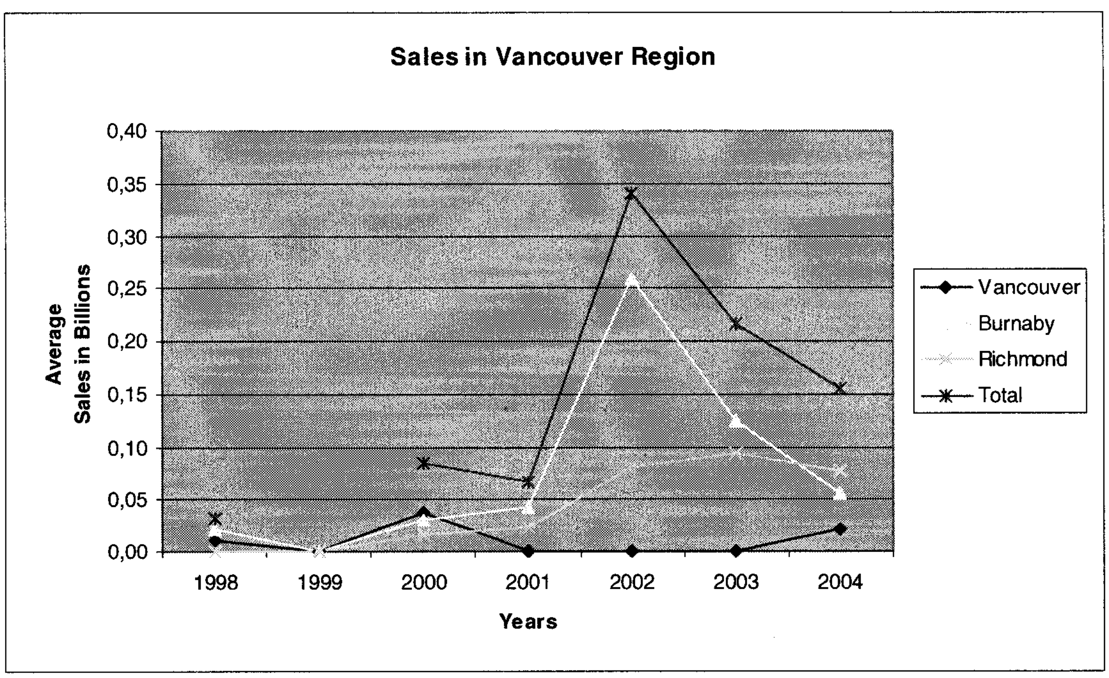


Figure A.4 Sales in Vancouver Cluster

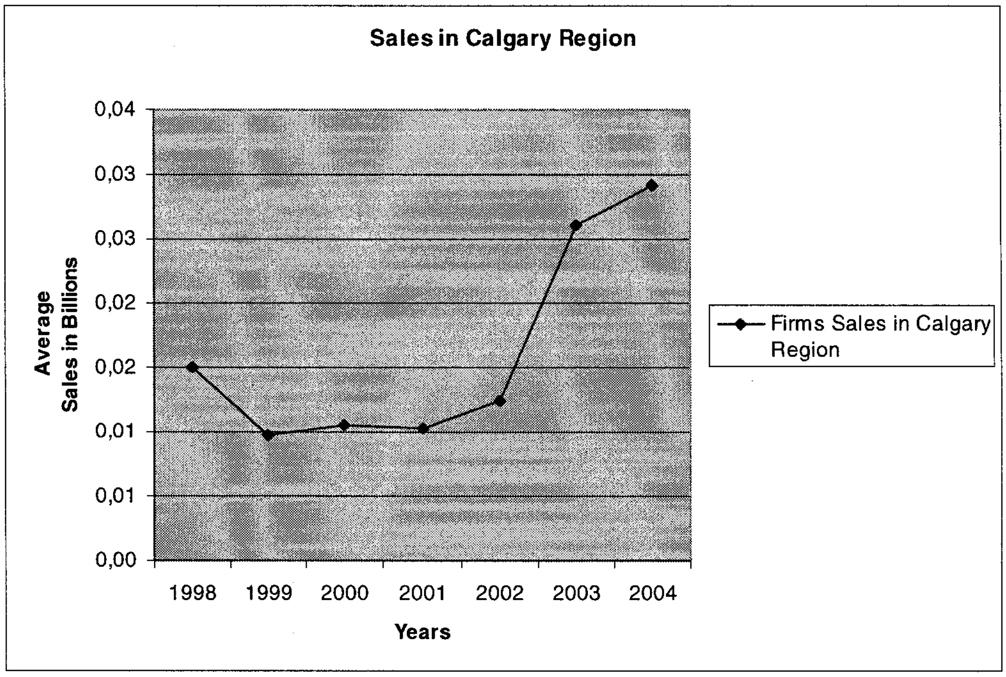
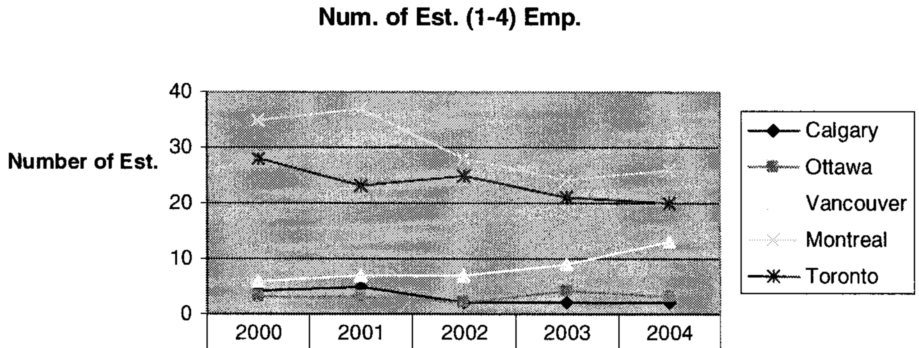


Figure A.5 Sales in Calgary Cluster

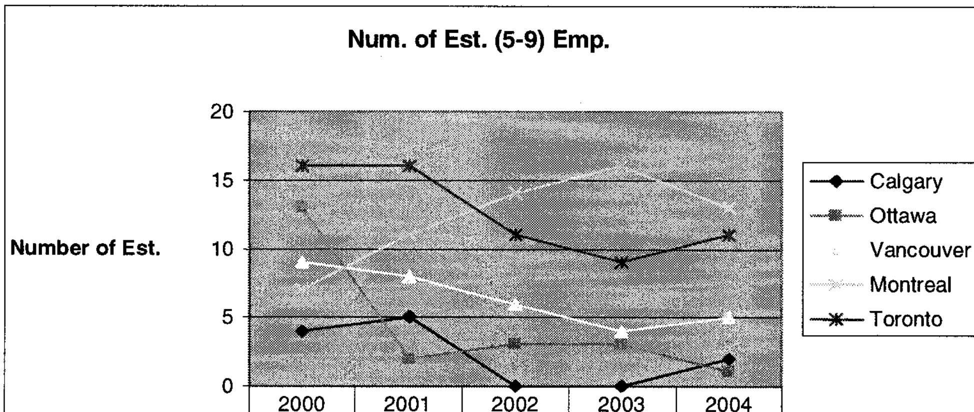
ANNEX B: NUMBER OF ESTABLISHMENTS PER EMPLOYEES CATEGORIES IN DIFFERENT CLUSTERS



	2000	2001	2002	2003	2004
Calgary	4	5	2	2	2
Ottawa	3	3	2	4	3
Vancouver	6	7	7	9	13
Montreal	35	37	28	24	26
Toronto	28	23	25	21	20

Years

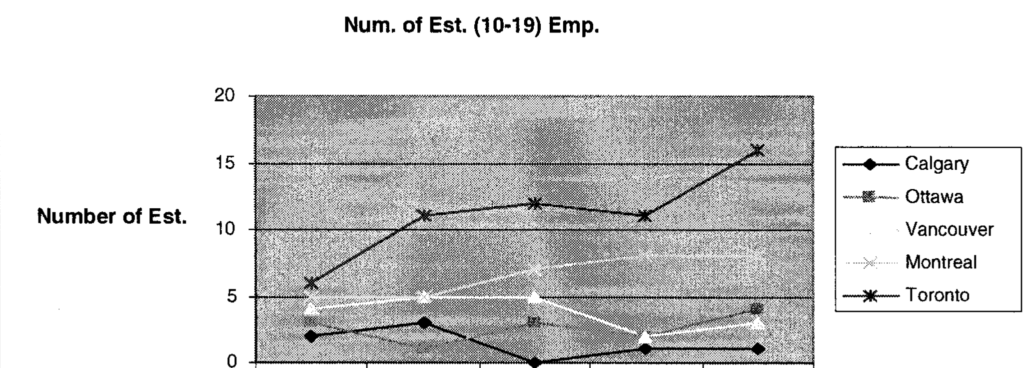
Figure B.1 Number of Est. (1-4) Category per cluster



	2000	2001	2002	2003	2004
Calgary	4	5	0	0	2
Ottawa	13	2	3	3	1
Vancouver	9	8	6	4	5
Montreal	7	11	14	16	13
Toronto	16	16	11	9	11

Years

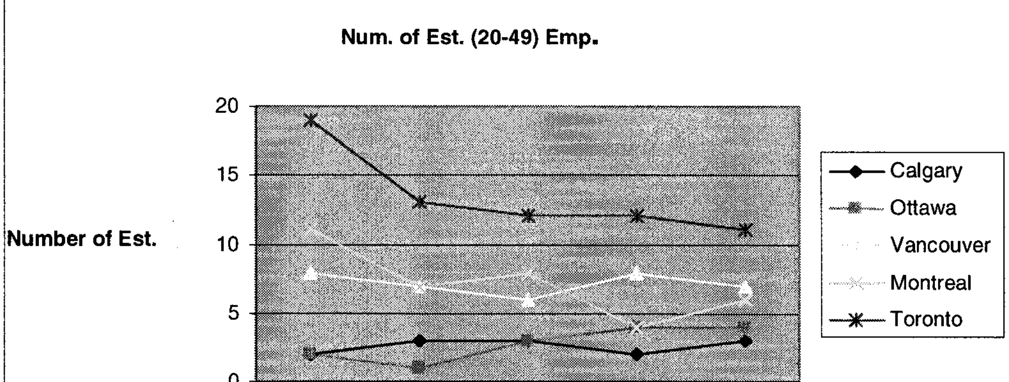
Figure B.2 Number of Est. (5-9) Category per cluster



	2000	2001	2002	2003	2004
Calgary	2	3	0	1	1
Ottawa	3	1	3	2	4
Vancouver	4	5	5	2	3
Montreal	5	5	7	8	8
Toronto	6	11	12	11	16

Years

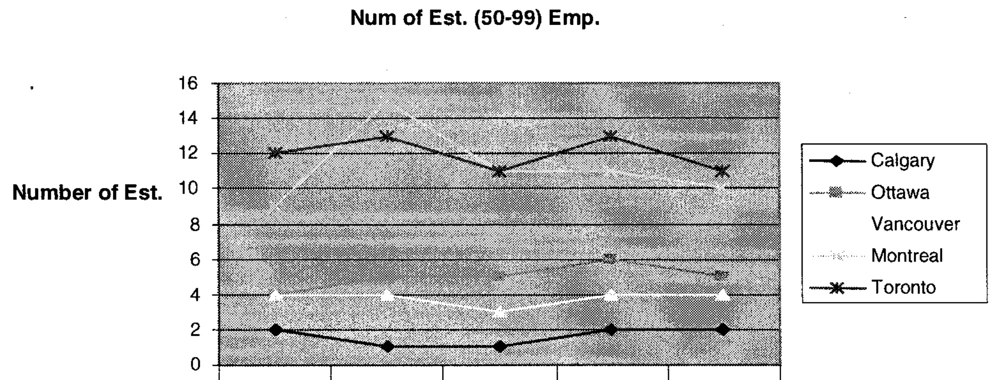
Figure B.3 Number of Est. (10-19) Category per cluster



	2000	2001	2002	2003	2004
Calgary	2	3	3	2	3
Ottawa	2	1	3	4	4
Vancouver	8	7	6	8	7
Montreal	11	7	8	4	6
Toronto	19	13	12	12	11

Years

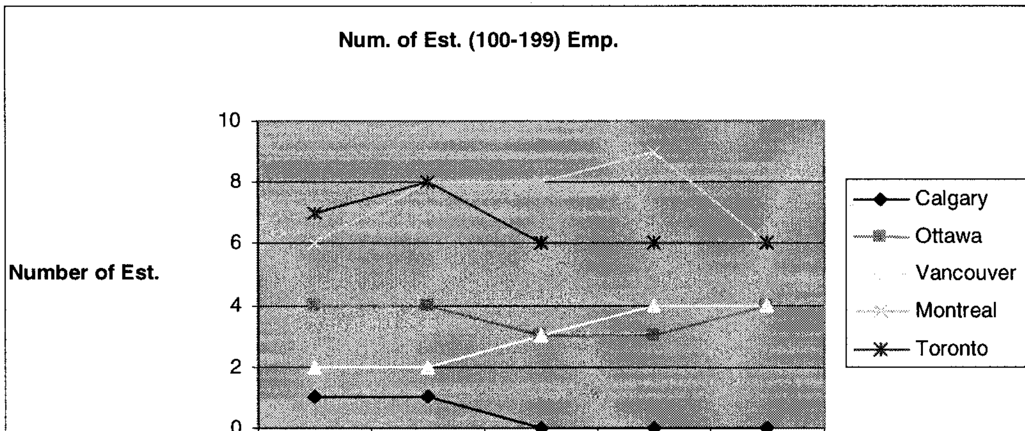
Figure B.4 Number of Est. (20-49) Category per cluster



	2000	2001	2002	2003	2004
Calgary	2	1	1	2	2
Ottawa	4	5	5	6	5
Vancouver	4	4	3	4	4
Montreal	9	15	11	11	10
Toronto	12	13	11	13	11

Years

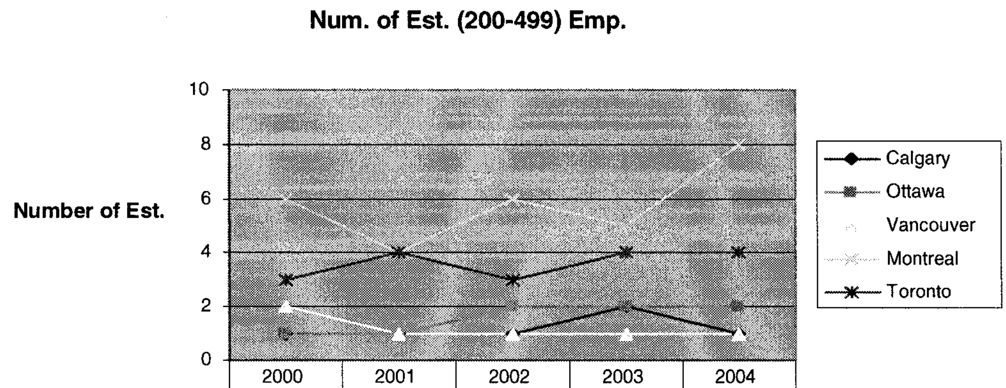
Figure B.5 Number of Est. (50-99) Category per cluster



	2000	2001	2002	2003	2004
Calgary	1	1	0	0	0
Ottawa	4	4	3	3	4
Vancouver	2	2	3	4	4
Montreal	6	8	8	9	6
Toronto	7	8	6	6	6

Years

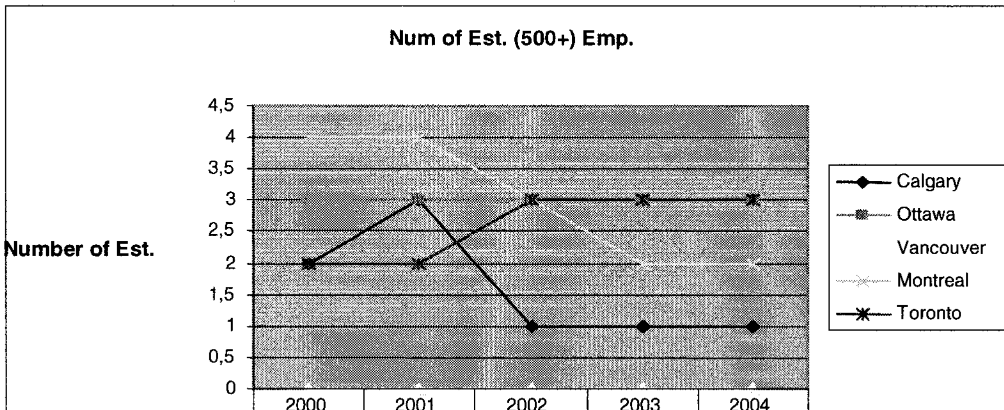
Figure B.6 Number of Est. (100-199) Category per cluster



	2000	2001	2002	2003	2004
Calgary	1	1	1	2	1
Ottawa	1	1	2	2	2
Vancouver	2	1	1	1	1
Montreal	6	4	6	5	8
Toronto	3	4	3	4	4

Years

Figure B.7 Number of Est. (200-499) Category per cluster



	2000	2001	2002	2003	2004
Calgary	2	3	1	1	1
Ottawa	3	3	3	3	3
Vancouver	0	0	0	0	0
Montreal	4	4	3	2	2
Toronto	2	2	3	3	3

Years

Figure B.8 Number of firms (500+) Category per cluster

ANNEX C: PATENTS EVOLUTION

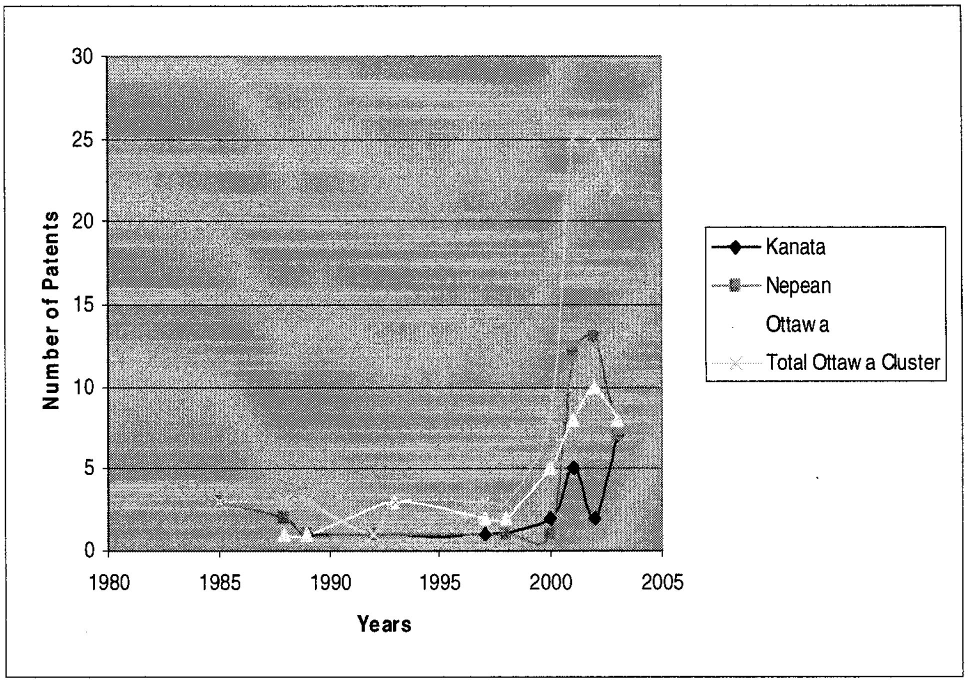


Figure C.1 Fibre Patent Evolution - Ottawa Cluster

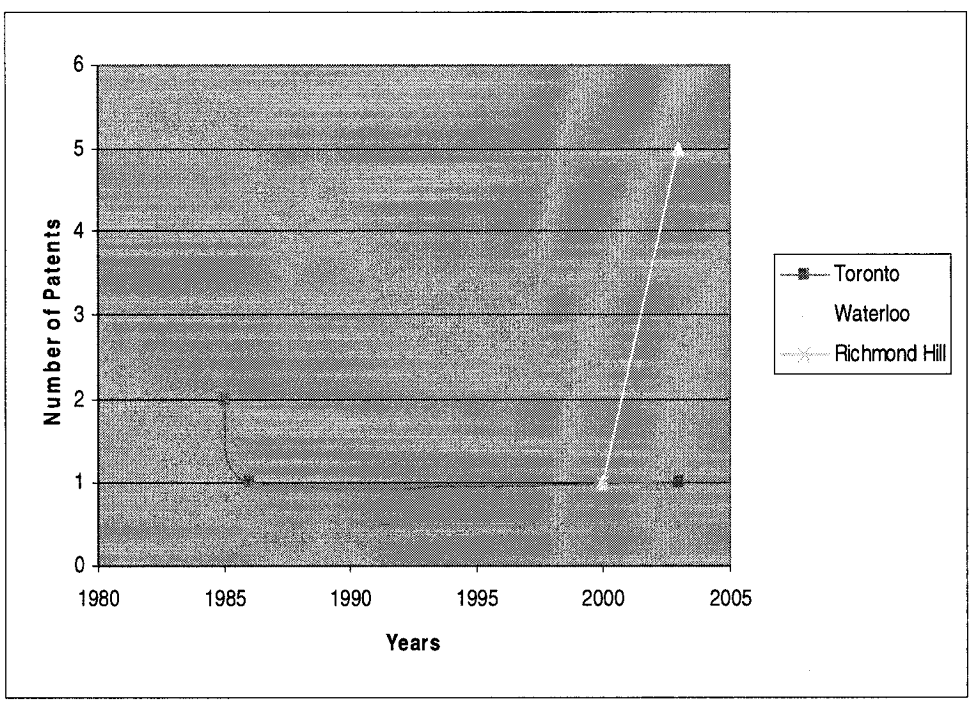


Figure C.2 Fibre Patent Evolution - Toronto and Waterloo

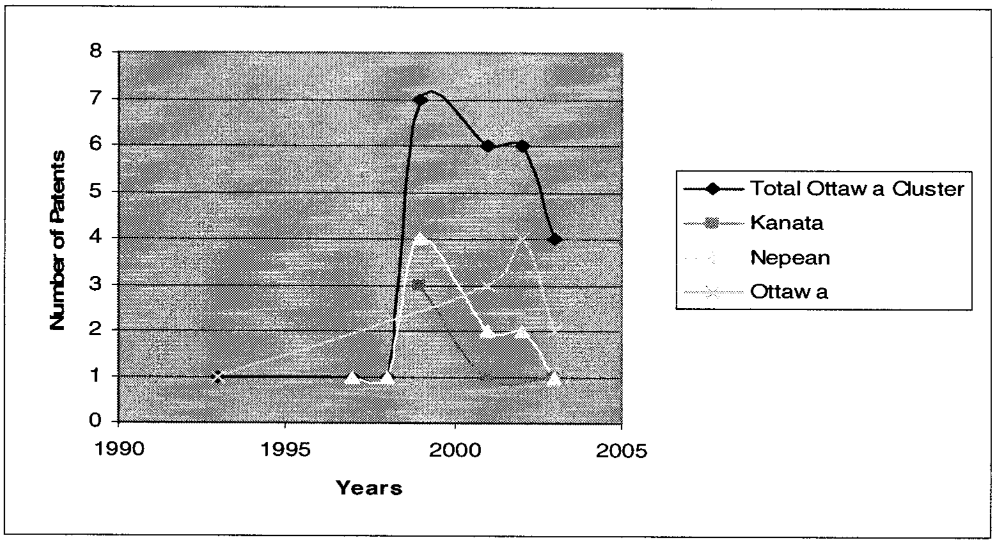


Figure C.3 Telecom Services Patents Evolution for the Ottawa Cluster

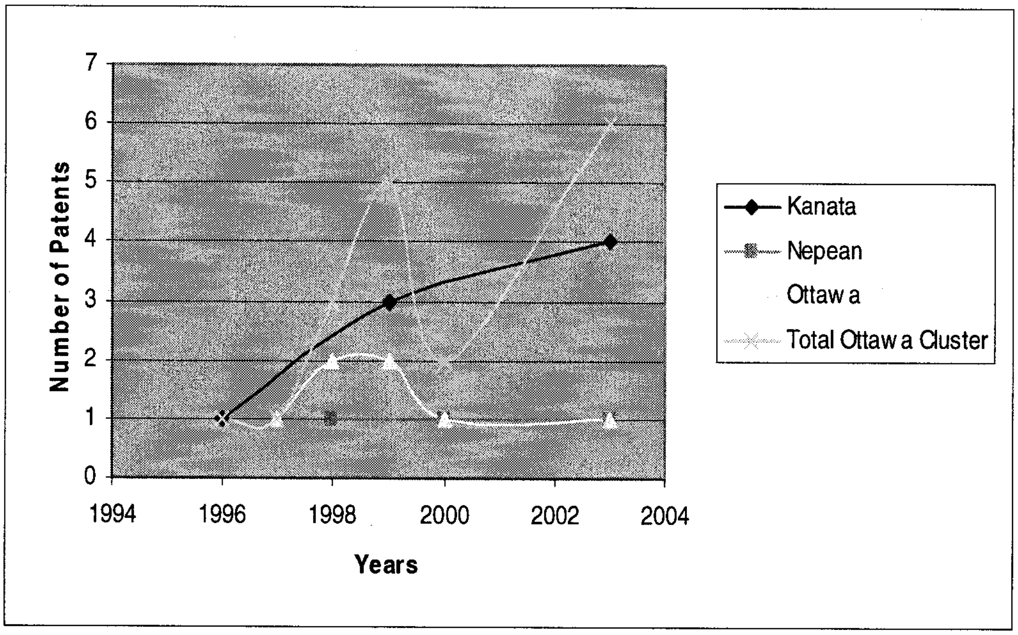


Figure C.4 Telecom Software Management (Ottawa Cluster)

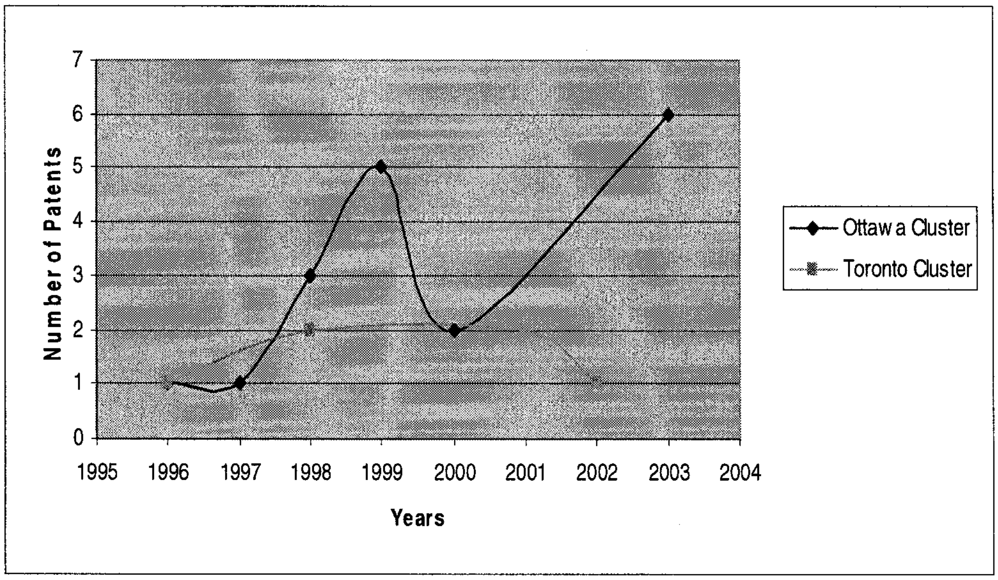


Figure C.5 Telecommunication Software Management (Ottawa and Toronto Clusters)

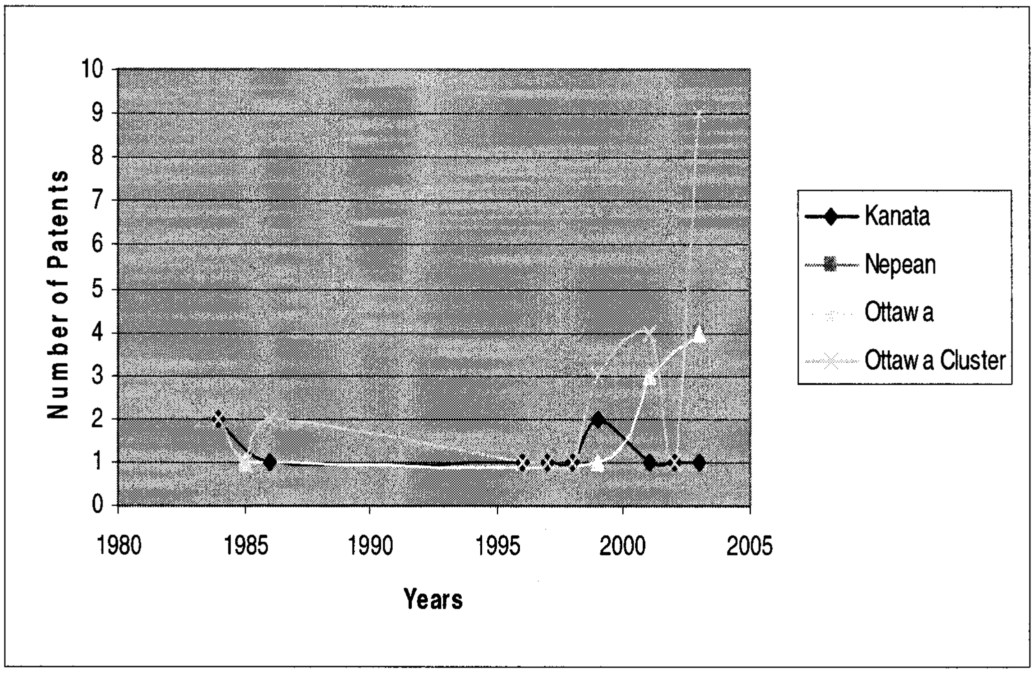


Figure C. 6 Voice Patents Evolution (Ottawa Cluster)